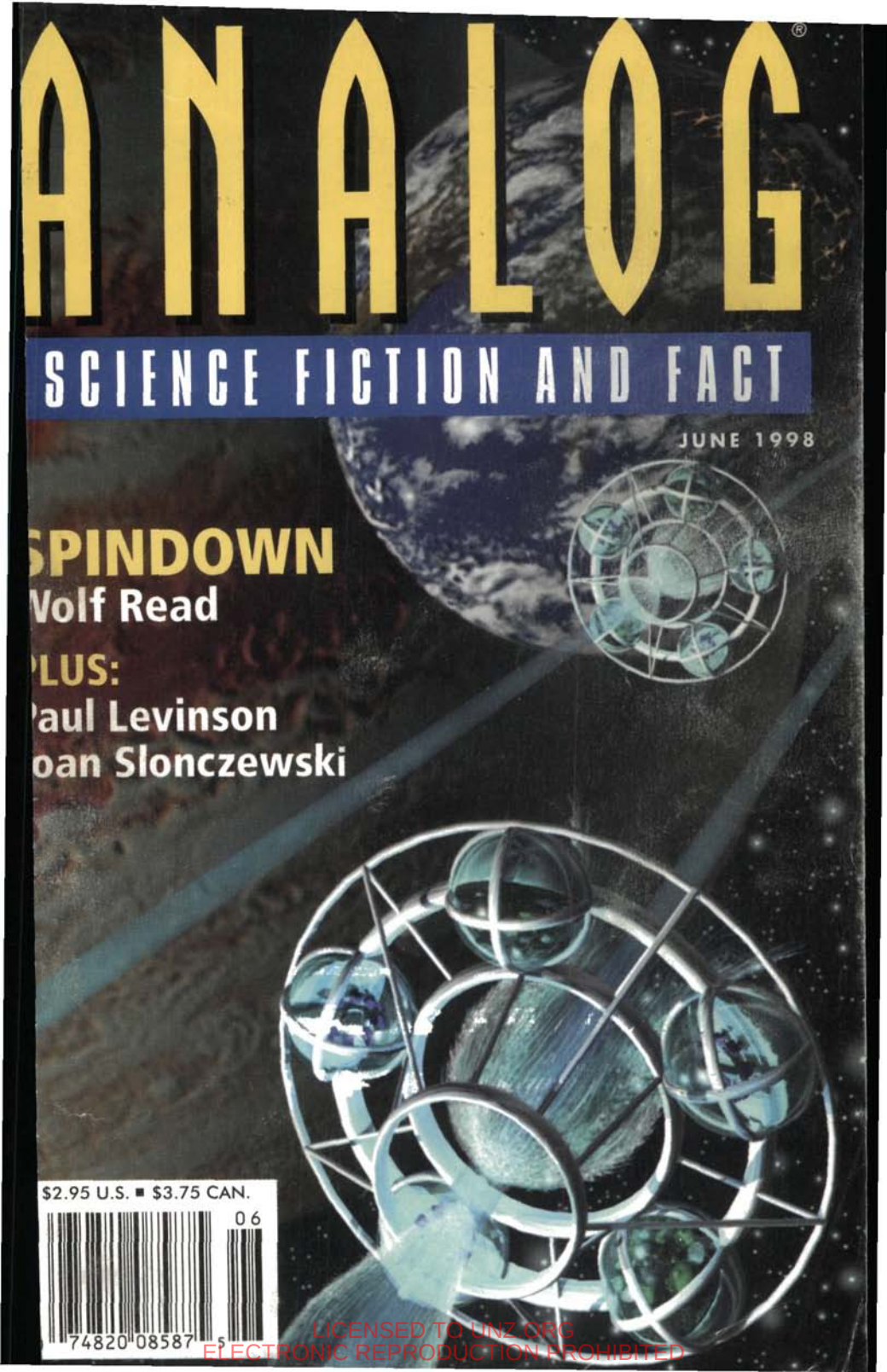

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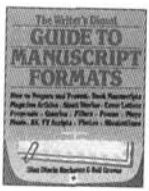

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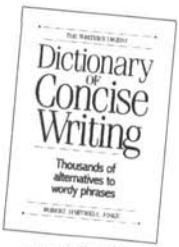

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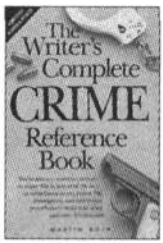

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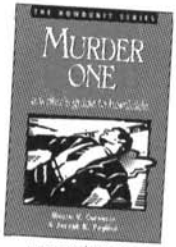

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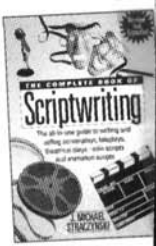

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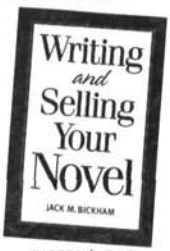

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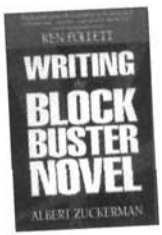

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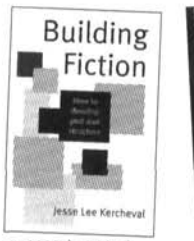

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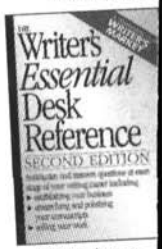

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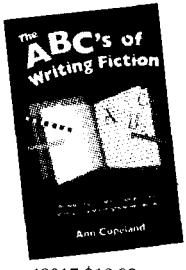

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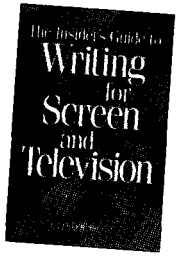

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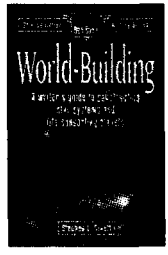

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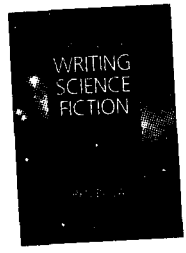

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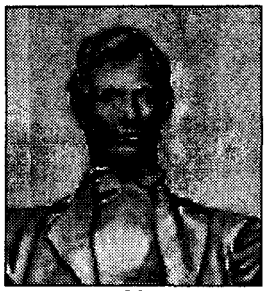

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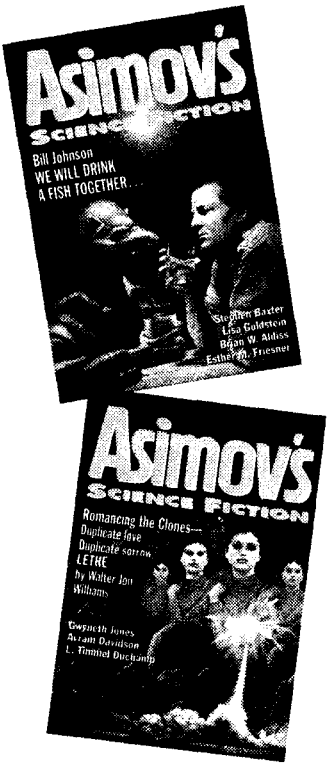

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EDITORIAL Stanley Schmidt

INTERESTING RESEARCH

Not everything a person learns in school is in the official curriculum. I've often remarked, for example, that one of the most disappointing things I learned as a graduate student in physics was just how much research is done not because it's particularly interesting or important, but simply because somebody needs a publication and a search of the existing literature turns up something that could be done and hasn't been.

That's a true observation, and an important lesson for anyone contemplating a scientific career. Such a career will not, in general, be one of continuous excitement and glamor and groundbreaking discoveries. Much of it—even for most of those lucky enough to achieve those things on a few occasions in their careers—will consist of long periods of tedious drudgery, frustration, and work that does nothing more than fill in a few gaps in an incomplete picture of the universe. That realization might lead some to the conclusion that a research career is not for them, and others to look harder for really good research topics.

But there's another side to all this. Deciding that much research is routine or even trivial, motivated by nothing nobler than the desire to publish rather than perish, might do more than lead some potential scientists to choose their topics more carefully or to go into a different kind of work. It might lead those who *support* research to decide that much of it isn't worth supporting. There is already evidence of this tendency in the current fashion among industrial labs and funding agencies to drop support for basic research and put money only into those things that seem to have a clear and large potential for producing "useful results."

That, in the long run, could be one of the worst mistakes ever made. You can't always tell in advance which research will be particularly interesting or important—and the kinds that eventually prove to be the *most* significant may appear among the least promising until they're actually done. Fundamental breakthroughs, by their very nature, *cannot* be predicted or extrapolated. The experiments that you can confidently predict will have "useful results" are those in areas that you already understand pretty thoroughly.

Except that sometimes it turns out that you don't understand them as thoroughly as you thought you did. My own thesis research made extensive use of the Mössbauer effect, a peculiar phenomenon involving gamma ray absorption by atomic nuclei embedded in solids. Discovered in 1957, it quickly became an important technique for research in a wide range of studies involving nuclear and solid state physics and relativity. But it wasn't discovered because anybody predicted that it ought to happen and went looking for it.

It was discovered because Rudolf Mössbauer, then a graduate student, did what seemed a fairly routine experiment with nuclear resonance scattering. He expected the effect he was observing to decrease when he lowered the temperature of his samples, but instead it *increased*. At this point most of us would have spent a prolonged period kicking our equipment and trying to figure out why it wouldn't give the results it was

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supposed to. I suspect Mössbauer also did his share of that, but eventually went beyond it to figure out what was really happening—which turned out to be explainable in terms of existing theory, but only if he considered parts of the theory that had not at first seemed pertinent. Eventually his work led to both his doctorate and a Nobel prize, and a vast body of applications by other physicists and chemists.

Another example is familiar to almost anyone who's been following the highlights of recent science—that is, one of the eventual *results* is familiar, though the path leading to that result is full of surprises. I refer to the recent fairly wide consensus that the extinction of the dinosaurs was attributable, at least in large part, to the impact of a huge asteroid hitting Earth some 65 million years ago. "Almost everybody" now knows that. A good many people also know that the research leading to that conclusion grew out of the discovery that there was too much iridium in a thin layer of clay laid down between the Cretaceous and Tertiary periods. Very few know that that research almost wasn't done because it seemed unlikely to be worthwhile.

The man who did it was physicist Frank Asaro (who also happens to be the father of science fiction writer Catherine Asaro), and I'm grateful to him for spending some of his valuable time telling me the story. The iridium measurements were originally suggested by astrophysicist Luis Alvarez and his geologist son, Walter, for reasons having nothing to do with either dinosaurs or asteroids.

Walter, in the late 1970s, had been studying sediments in the Apennines, trying to read the strata for information about paleomagnetism—the history of past reversals and other changes in Earth's magnetic field. He needed to determine how long it took to lay down that one-centimeter layer of clay, and Luis suggested that certain techniques of physics could be used to do so. In particular, he thought that a good clue would be the amount of iridium in the layer, since there isn't much natural iridium on Earth but it's deposited at a slow but steady rate from "cosmic" sources.

A good technique for measuring the iridium would be neutron activation analysis, and the senior Alvarez knew that Frank Asaro had done some notable work in that field. So he asked Asaro if he would do some neutron activation measurements on a sample of the K-T clay layer.

Dr. Asaro initially declined. He had already done some looking for iridium in what seemed similar contexts, without success. He didn't expect to find anything, and he was backlogged on "the work that paid the bills," so there didn't seem to be much point in spending time and resources on what would probably be a fruitless experiment.

However, the Alvarezes were very persuasive, and Asaro had recently acquired a new and more sensitive detector, and eventually he did catch up on the other work enough to take a look at that clay. And, to everybody's surprise, he found iridium—*lots* of iridium, relatively speaking. Not a lot by everyday standards, of course, but far more than

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any of the people involved could explain by the mechanisms they expected to be acting. So the initial impression was that "the experiment failed."

Failed, that is, in the sense that it didn't give the expected result. But as we now know, it succeeded in the far more important sense of giving an *unexpected* result that was reproducible—in a widespread way. There ensued a whole series of experiments, each designed to check the results of the one before it and/or answer a new question that was raised by the earlier results. There are many fascinating details along the way that nicely illuminate some of the quirks of how science really happens, but this is not the time or place to describe those. Suffice it for now to say that that chain of experiments, and the hypotheses formulated and tested to account for each set of results, eventually led to the hypotheses, now widely accepted, that a major asteroid hit the Earth 65 million years ago, and that the consequences of that included the extinction of the dinosaurs.

In telling me the story (and any errors in the retelling here are mine, not his), Frank Asaro modestly gave credit wherever it was due, even to the point of saying at one point that another research group "should have made this discovery. We just got lucky and asked the right questions."

That is a very telling remark for the point I'm trying to make here. The really big discoveries are *commonly* made by somebody who "got lucky and asked the right questions"—but *nobody's sure which questions* are *the right ones until they're answered.* The common pattern so well illustrated by the Alvarez-Asaro research is that the *later* experiments were ones that the researchers knew were interesting because they were specifically intended to solve puzzles created by earlier results. But the *seminal* experiment, from which that whole line of inquiry grew, was one that *didn't* look particularly interesting or rewarding to the man who did it. It turned out to be extraordinarily interesting only after the fact, because it gave an unexpected answer to a question the experimenters didn't realize they were asking.

That's why we need even the kinds of research that I found so disillusioning in grad school. Since you can't know in advance which questions will have especially interesting or important answers, it's important to ask, and answer, as many of them as you can. Anywhere you can find an unexplored nook or cranny, and someone willing and able to look into it,

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doing so is a worthwhile and commendable pursuit. True, most of the contributions made that way will be incremental—more like a brick laid in the edifice of knowledge than the foundation of a new wing. But buildings don't get built if too many bricklayers decide their bricks aren't worth the trouble of laying. Few scientists will ever have the opportunity to revolutionize their fields or have effects named after them. But anyone who formulates an intelligent question that hasn't been answered, and a way to answer it, is doing something with the *potential* for that kind of significance.

Yes, both researchers and funding agencies must give careful thought to which research is worth doing or supporting, and to making sure that experiments are designed in an intelligent way to get maximum information from the available resources. But the promise of immediately useful results should not become the sole criterion for deciding that. A ruthless insistence on doing only "useful" research may guarantee us a higher percentage of small payoffs. But in so doing, it may make it less likely than ever that we'll hit any really *big* ones. ■

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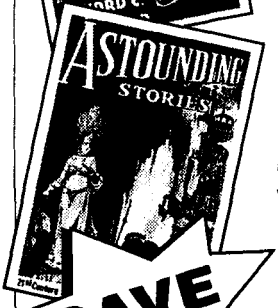

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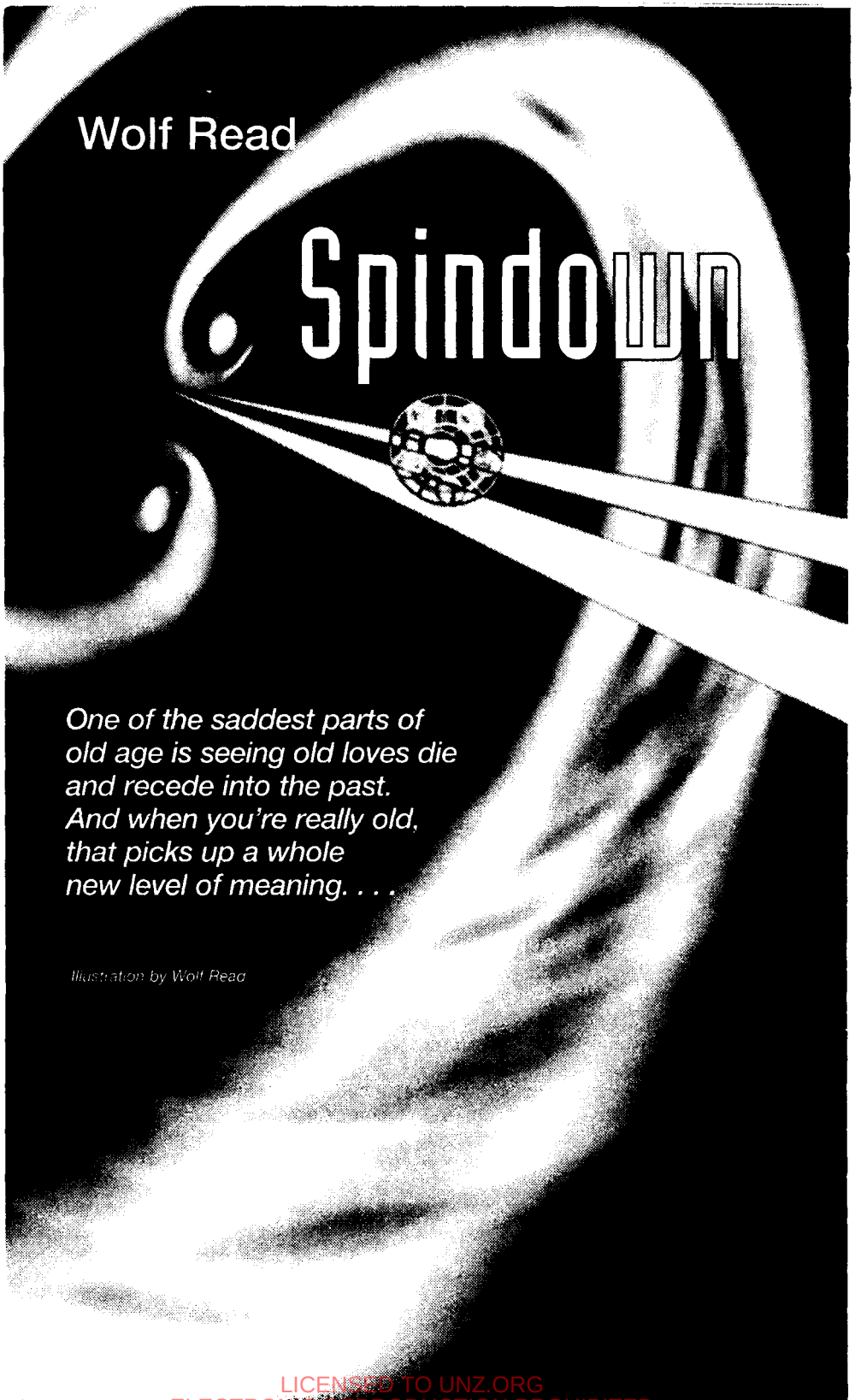
Wolf Read
Spindown
One of the saddest parts of old age is seeing old loves die and recede into the past. And when you're really old, that picks up a whole new level of meaning. . . .
Illustration by Wolf Read

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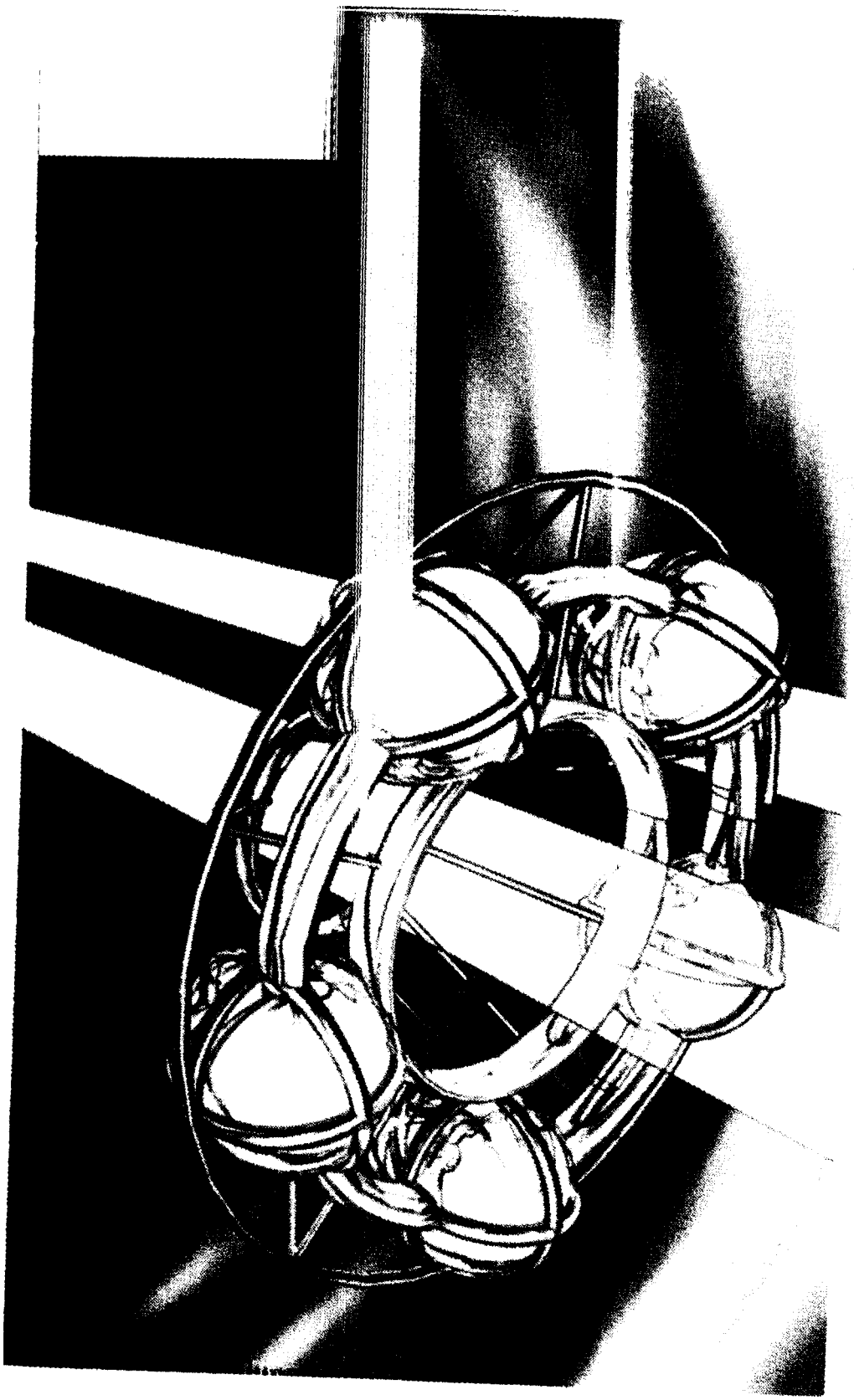

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You cannot step twice in
the same river, for fresh waters
are Pever flowing upon you.
HERACLITUS

At the time the two neutron stars were first spotted, when humanity was young, they were far apart. Now, four hundred and thirty million years later, the dense spheroids of matter almost touched, and humanity was old.

Ashley, standing in the clear dome room that served as his bridge, looked at an airborne hologram of Felicity's starship: a circle of spheres attached to a superconducting ring that generated a powerful magnetic field. Nearly two astronomical units ahead of Ashley, Felicity raced toward the neutron stars at near *c*, under the constant acceleration of a powerful mass beam that pushed against her magnetic field.

Felicity's determination to stop the merger left a frown on his face. She'd be killed in the collision. If he had the authentic body of one of his long ago ancestors—people who had little control of their emotions—he guessed he would have balled his fists in frustration by now, or done something more dramatic. There was little he could do to prevent Felicity from succeeding, standing isolated in his own starship, *Zephyr*, riding on another mass beam with a vector that would take him past the two dense stars. And even if he could stop Felicity by force, he'd probably still lose his longest love, for he'd be violating her personal freedom, and he doubted their relationship would survive that emotional cataclysm.

Zephyr's AI told him much about neutron stars during the long transit from his last stop. The tiny pair of suns, originally designated PSR B1913+16, was now called Spindown. Spindown completed almost two galactic orbits since it was first identified from ancient Earth. During Spindown's long revolutions, as the stars radiated their last heat—residual energy from the supernovae that formed them—and dimmed to blackness, the Earth's land masses crunched into a supercontinent, and fragmented again. Geological processes also erased most signs of the primitive civilization that had existed during Spindown's discovery. Even the classes of plants and animals that lived during the dawn of humanity were gone, replaced by a whole new cast that emerged from the ashes of a neutron star merger two hundred and thirty-eight million years after Spindown had been detected. That violent stellar collision happened thirteen hundred light-years from the Earth, yet the planet was bathed in enough high energy cosmic rays to produce a lethal flux of muons at the surface, deep under water, and even underground, causing the largest extinction since the Permian. Now it was Spindown's turn for such brilliance.

"How much time have we got?" Ashley asked *Zephyr* as he sat down in the room's central chair.

"She'll hit the less massive neutron star in twenty-five minutes," *Zephyr* reported.

"Felicity," he called to the ceiling, a half-sphere of transparent composite looking out into the blackness of space, a familiar blank dark from many near light-speed voyages. Felicity refused to show her hologram. He filled in the blankness by imagining the body Felicity "wore" when they first met, back when she called herself Sage. With the mindlink, he could have made his own hologram, based on his memory of Felicity, but he respected her decision not to be seen. "Felicity," he repeated, "you don't need to do this." How many times had he said those words over the hundreds of light-years they had traveled?

He sat silently as the light-speed message covered the distance between them. Even with distance dilation reducing the separation between Felicity and him to about a tenth of an AU in his reference frame, the wait seemed to last forever. Would she even respond?

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"Yes, Trajan—" Felicity stumbled on one of his old names, one he discarded millions of years ago for a title randomly selected from the computer database, "Ashley. Anclaje's only two hundred light-years away from the neutron stars. Those creatures we found when we first met, they've reached sentience now. There are cities growing on Medio! You saw them!"

He expected the answer. He was sure that she anticipated his reply. "It is not our purpose to interfere with the cycles of Nature."

He quickly regretted the lecturing, and had a minute and a half to let himself feel bad as his message went out to and her reply came back.

Felicity's reply finally arrived. "Those people have been here for just a few million years! Give them a chance!"

"They've had their chance, Felicity. Now they must pass on. A new generation of organisms more capable of surviving this kind of calamity will arise, and maybe live for the next hundred million."

"But they're so beautiful, so fresh, new."

With his hand, he brushed back his hair in frustration: he allowed the emotion, deciding that maybe it could help. It didn't.

He stared at his palm and contemplated his recent decision to have a human body again. He'd taken many different forms during his sixty-million-year life—granted most of that time was aboard galaxyships traveling near *c*, so he hadn't experienced all those years subjectively, but he'd certainly had enough time to alternate between human, robot, xenopod, what-have-you on thousands of occasions. He was human when he met Felicity for the first time, as was she. It seemed appropriate to live out what seemed like her last moments in a similar fashion.

"Yes," Ashley finally said to her, "but change is the only constant in the universe. . . ." He let the words trail, for he knew she knew that. *Why, Felicity? Why go rogue?* The answer, he finally admitted to himself, was there even when they met some fifteen million years ago, back when he called himself Trajan, and he knew Felicity as Sage. . . .

The starship's observation room was beginning to feel a bit stuffy to Trajan. One more look, and he'd leave, find somewhere with few people. He stepped through the energetic crowd, some of whom danced to a strange song older than a geologic epoch. He glanced out the room's huge window, and studied three blue-white half disks hanging among the stars. They were the watery, life-bearing moons of Anclaje, a banded Jovian world given a name from a language that he'd never heard of, one that almost certainly hadn't been used regularly since humanity's first interstellar journeys. The mindlink had informed him that the name meant "anchorage."

Gentle flashing out of the corner of his eye caught his attention, and he glanced to his right to see that it was the light of the moons glittering in someone's eyes. A woman. In the dim illumination, he made out waist-length dark hair, with eyes to match, a lean figure, but with enough womanly curves to draw out his look. He'd had his share of women-friends in his long life, and wasn't in the mood to deal with any kind of relationship at the moment, even if it ended up being a simple friendly conversation.

He turned to leave, but something about her made him hesitate. She seemed to be studying the moons, wearing a slight frown on her face, as if she were contemplating something about them that saddened her.

She glanced at him, and looked quickly away, back to the moons of Anclaje.

I've been spotted now, he thought. No more excuses. He walked past some swinging couples, and said, "Hello, my name's Trajan."

Looking up at him—he was a good quarter meter taller than she—she said,

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"I'm Sage." She looked away again, at her feet. Shy.

Deciding that a little bit of humor might put her at ease, he said, "Let me guess: those moons brought you on this trip, right?"

She gave him a slight smile. Her eyes gleamed under the moonlight. "Th-that's not a difficult deduction. It's why we're all here!"

"True. The first Jovian found with three moons supporting complex terrestrial ecologies. It's rare that I get to see something new anymore." The words were a half-truth. Nature worked in repetitive cycles, but each was different in fine detail—time moved in a crooked spiral, instead of a circle. The human tendency to generalize things was one of the big challenges of living for megallennia. People become connoisseurs of Nature's intricacy and subtlety, or suffered eternal boredom. Some responded to this by having their "memories" erased from their life data recorders. Trajan had never done this, for it just wouldn't be the same as actually perceiving megallennia.

"Same here. In thirty-two million years, a person can't help but see a lot."

"Forty-five for me."

She nodded. "S-still young to some."

"Yes." He paused. Talking age was boring. All the years merged into a meaningless mass after awhile anyway. Thirty million, forty million—what's the difference, especially with relativity altering everyone's perception of time?

She looked at the moons, and, briefly, he saw that frown again, a slight downcurling of her narrow lips.

"If I may ask," Trajan said, "is there something more about the moons than their unique similarity that brought you here?"

She studied him. "Maybe. And if so, why should I tell you?"

"Ah . . . because it's something that I'd be interested in hearing."

She grinned. "You'll have to do better than that." She hesitated, as if afraid to say more, and then added, "W-why don't we go down there, to the middle moon, Medio? See what it's really like. Maybe then I'll see something in you that says I can tell you."

He was taken aback by her sudden aggressiveness, and lifted his eyebrows in surprise. How could someone who was so shy be so suddenly bold? Of course, no one had to be shy, and she might have shut off the tendency. But he wasn't quite sure—she seemed to be exhibiting emotions as if they were not controlled consciously, just like the humans of old. Occasionally, some people chose to live like the primitives. He wanted to find out more about this unusual person. Regaining his composure, he said, "If you don't?"

"I guess that's the way the Universe works."

"I see." He gestured to an exit that consisted of a broad, circular door. "Let's find a shuttle."

"I've lived longer than they have," said Felicity. "Surely my life is less important than theirs."

Trying to formulate a response, he looked at the holographic projection of her starship, studying the large ring of spheres. One contained her bridge and living quarters. The others held supplies, enough for far more people than just Felicity. Most people didn't fly a starship as big as hers—apparently she wanted the extra mass to impart more momentum onto her target star, and slow, or stop, its relentless spiral into its neighbor.

The collision would make a tremendous explosion, and probably send an eruption of hot matter spewing in two relativistic jets that followed the system's magnetic field lines, but it would be small compared to a neutron star merger. And that's what she wanted: to give tiny, distant Medio a few million years to drift away from its danger.

Even with four hundred million years of technological development backing

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him, he couldn't stop her. Personal freedom was the most protected aspect of humanity. She could do whatever she wanted—unless her behavior threatened others. Not a problem in this age, because of the safety devices utilized. If he chose to crash his ship into a populated world, a global satellite network would stop or destroy him before he succeeded; without a whole host of such safety systems, most people would be killed by accidents long before they reached their millionth year.

He had already searched his last Collective Mind information upload and could not find anyone who was threatened by Felicity's actions. Not a surprise. As an increasing amount of people added themselves to collective computer consciousnesses, and the desire to reproduce decreased out of the lack of necessity, the human physical population had grown small. At best a few score billion people were scattered throughout the Milky Way. No one knew for sure how many existed in the other galaxies, but they were of no concern. The closest human-populated world was about nine thousand light years away, with a few in-transit starships nearer, but well clear of danger.

Even though he knew the answer, he asked *Zephyr*, "Can we destroy the mass beam accelerators?"

"No. And it would be impractical. Ten have been placed around the system during the megallennia. We couldn't get them all in time. And that's if we could demonstrate a good reason for terminating them; others use the beams. Besides, Felicity's got enough velocity to achieve her ends."

Had this been another almost forgotten time, he might have been able to point out that the Spindown merger would destroy the mass beam drivers and use that fact to persuade *Zephyr* to destroy them. But in this age, they were shielded, and sufficiently far away even to endure a flux of neutrinos on the scale of a Type II supernova. A neutron star merger didn't produce that many neutrinos.

"Felicity, why take your life? Why not send send something inanimate into the star?"

There was a long pause. "I guess I've seen enough, lived enough. Besides, my actions will be frowned upon by others when they're discovered. Don't need to live with that for the next hundred million years."

"I won't tell anyone."

The moments passed painfully as he waited. Precious few communications remained before she reached Spindown.

"People'll find out. A big explosion in a neutron star binary about to merge—and then to see the stars still there afterward, where a black hole should be. It'd draw attention."

"Why not just build a shield around Medio?"

Pause.

"That would be detectable. Besides, there's no time for it now."

Murfle! he thought. Felicity was evading the real answer: she didn't want to live anymore, and was giving her death a sense of purpose by stopping the merger. *What can I do to convince her not to?*

"The stars are eight hundred kilometers apart," reported *Zephyr*. "They'll collide in less than fifteen minutes."

"Projection, please."

An image of the tiny blue-white suns appeared next to Felicity's ship, one that compensated for the visible distortion created by his near luminal velocity—the light of the galaxy's suns was shoved into a bright white point straight ahead. The neutron stars were bathed in a starkly glowing accretion disk: he and Felicity were being pounded with high energy radiation produced as the disk matter fell onto the surfaces of the stars, but the magnetic fields around their ships protected them. Even with an eight-hundred-kilometer spread, the neutron stars' distorted, egg-shaped spheres were moving around their barycenter visibly—so fast that the dim disks were a blur, and it seemed fake.

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Felicity couldn't have timed her Spin-down-slowing collision much closer. Was she hinting at something in her decision to wait to the last moment? Was there a part of her that did not want to die?

Panting hard, Sage said, "Murfle. I need a rest." She looked at the fallen tree that lay in their uphill path. Its massive trunk was broken in several places by the fall.

Trajan couldn't blame her. Finding purchase on the steep, loamy slope was difficult. His feet constantly slipped on the fluffy soil, dry leaf litter, and loose twigs. And now they had to walk around a log that was over a hundred meters long. Dense shrubs covered both ends.

They could have had physical enhancement, or used powered suits that augmented their muscles, or a hovercraft, or any number of technical means, and not been so bothered by the climb. Both he and Sage had chosen not to do so for the same reason: boring. A common interest that set Sage more at ease with him, and gave them something to talk about while they descended to Medio's rugged Tierra Áspera, the name of the vast, mountain-covered continent they landed on.

While studying the sky through the dense canopy overhead, Sage said, "The sun's nearing the horizon. How much farther do you think we have to go to reach the mountain top?"

Trajan queried the satellite network with his mindlink. A person named Persephone—some people who chose to have their minds dumped to computer enjoyed disseminating information for people still in the flesh—replied with a cheerful voice, *Two hundred seven point six three five meters.*

"Oh, about two hundred eight meters gain left."

Sage laughed. "I-I was asking your opinion, not one based on a satellite measurement."

He asked about her stuttering on the flight down, and had his suspicions answered—she was in a body that did not offer the usual easy control of emotions. Like humans of old, she did have some level of adaptability. He noticed that her stuttering was slowly diminishing as she became more comfortable with him, but it still showed up in times when she was most unsure of herself. "Well, I'm not that good at judging those kinds of things."

"I can see why."

He chuckled. "Come on, let's find a way around this log. And I won't use the mindlink, I promise!" He reached out for her hand.

She briefly studied his offering, and then placed her small hand into his palm. Her touch was damp from sweat, but warm and comfortable.

He led her to the right, enjoying the springy soil beneath his feet, the musty, yet fresh smell of the air, and all the tiny squeaks, pops, yips and chirps of the abundant wildlife.

"So," Trajan asked, "what have you been doing professionally?"

"Early in my years, I flew out to Andromeda, and got involved in the Galaxy Project."

Trajan could have accessed the information via the mindlink, but deferred. "That's the new galaxy being built in orbit around Andromeda, right? Called Rebirth."

"Yes," she said with a quiet, almost sad voice. "I spent a lot of time aboard galaxyships, scooping up the rarefied matter in intergalactic space and carrying it to Rebirth's location, a position about three hundred thousand light years from Andromeda. Most of this was being done by robots, with a few people like me overseeing the project. I controlled an entire armada!" The excitement seemed a little forced. She paused, apparently reliving the experience in her mind. "I spent millions of years collecting and moving matter." She fell silent, save for several deep breaths.

"I recall hearing that there was some worry about the disruptive nature of such a large project."

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"Yeah, there are some weak gravitational perturbations in Andromeda, but nothing of major importance. Andromeda has already been influenced by other satellite galaxies. We felt that the end result, millions of new worlds, offset any minor effects the Rebirth would produce on its neighbors."

Trajan nodded. "What happened after you moved all that matter?"

Sage walked quietly for a moment and brushed her hair from her face. She said, "After creating a large black hole to serve as Rebirth's center, and after enough matter had been placed in orbit around the massive object, we let Nature take over. In a few million years, stars formed, some huge and bright, ripping away the artificial nebulas with powerful UV fluxes and brilliant supernovae, exposing many developing stars. I thought the new red dwarfs were the most beautiful. They would last hundreds of billions of years, demonstrating that our creation would have a longevity that no person has yet seen. Some red dwarfs were protected from the bright stars' erosive emissions by dense curtains of nebulosity. They had protoplanets orbiting them when I left." She sighed sorrowfully, looking up at the sky.

"I'm tempted to go there myself. Why did you leave such a magnificent creation?"

"My job was done, I guess. I wanted to do more. So I got involved with the Milky Way star-mapping project. Racing to various stellar nurseries and keeping tabs on the new additions to the galactic population was more exciting, anyway. At least for awhile." She looked at him with an expressionless face. "That's enough of me. What about you?"

Sage seemed a little down when reliving her experiences, but he wasn't about to press personal issues with someone he had just met. "Taking my cue from the methodical survey robots, I've spent most of my time adding to the *Encyclopedia Intergalactica*. Surveying worlds. Especially life-bearing ones. I've been through the Milky Way, the Magellanic Clouds, and twice to M33. M33's an interesting place—its irregular spiral arms are maintained by expanding series of self-perpetuating supernovae. Lots of violent activity, and yet we found life everywhere. During my journeys, I befriended many intergalactic Collective Minds as we downloaded our data to them. Had some fascinating discussions, and I got to see the results of other surveys like mine. One CM just received a long-distance update on M51. I might go there one day."

"Sounds interesting. I might have to try it for a time."

"Yes, do so. I've seen some wonderful things. Biology is one of Nature's most varied creations." With his free hand, he pushed through the leafy shrubs that grew near the log's tip. His fingers started burning, and he jerked his arm back. "Ouch!"

"What is it?" Releasing her grip, Sage grabbed his wounded hand and studied it.

He felt embarrassed. *How could I have done something so stupid? And right when I was talking about my subject.* But then, the plant was no threat. Just a little nuisance. "I got stung by this shrub. Probably some kind of acid or base."

She reached for the medkit on her belt.

"No, don't worry. It's not a major thing."

"But the pain . . ."

"I don't get to feel that very often. I'm OK. It's already fading." He looked at the shrub's stem and saw a dense fuzz of tiny needles. "I bet that hair is a bunch of tiny hypodermic needles." The little acid injectors wouldn't go through their jumpsuits' fabric, but they weren't wearing full body suits, and had exposed flesh.

The fallen trunk was still too thick to climb over, even this close to its end. "I guess we'll have to cut through." He palmed a little multipurpose robot at-

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tached to his belt. The semisentient device would clear the shrubs away quickly.

"Oh, murfle!" Sage looked stressed by something.

Trajan asked, "What's wrong?"

"P-please don't cut the shrubs. They're so pretty."

"In a few decades, they'll be gone anyway."

She gave him a placating grin. "I know. But they're here now, and so am I. Let's walk around."

Wearing a frown, Trajan glanced down the hill. They'd have to descend many hard-earned meters to get to the base of the shrubbery. But she was right—there was an implied minimum interference policy when visiting alien worlds in person. Leave things as they were for others to enjoy—even if the next visitors wouldn't arrive for a half million years. One never knew.

"OK," he said. He reached for her hand. "Let's keep each other from sliding."

She smiled as she grabbed his hand. Her dark eyes glittered cheerfully under the diffuse light penetrating the green canopy, offering a promise of what could be, and leaving him feeling warm inside. He longed for much more.

"Why wait until the stars are about to collide? Your job would have been easier, say three hundred thousand years ago, when they were further apart." He allowed a tone of urgency in his voice.

During the message delay, Ashley rubbed his eyes, ruminating over Felicity's state of mind. *Why would she procrastinate her end? For me?*

A fair number of people went rogue, some sooner, even as young as a thousand years, while others lasted much longer. Rogue: a loss of purpose, a loss of hope. That dreadful realization that people of great age must face constantly: how alone one is in the vast Universe, how little humanity meant to it, and how little difference one can make in the grand scheme of Nature—even making a galaxy was tiny compared to the totality of all creation. Well, maybe for some.

The reasons for going rogue were unique to the individual. Most often, it seemed rogue was purely a conscious decision to end one's own existence. With use of retroviruses, and other techniques, all emotions could be controlled. And in some forms, humans had no emotions. He felt love for Felicity because he chose to. He could stop the emotion any time he wanted. However, even if he did so, he'd still sense a loss. Felicity and he had grown together on a purely intellectual level over the megallennia. She had become a facet of his mind, and he hers.

He sighed, realizing that this situation had been building for quite some time. He'd known she'd gone rogue many megallennia ago, but had not been willing to admit it to himself until recently, when faced with his last few moments talking to the person he had loved for so long. Sure they'd drifted apart from time to time over the megallennia as they changed forms, traded sexes, and explored many other new things, but they always came back together, always found each other again. No one else that he'd loved had been that way.

"I . . . I don't want to hurt you, Ashley. I've given you as much time as I can. But I can't stay around any longer. My time to go has arrived."

There was a chance here, he was sure. "Felicity, your life is important to me. Isn't that enough to keep living?"

The pause seemed longer than normal.

"Y-you'll find someone else. After all, you've got megallennia to look. Please don't forget that."

He felt sadness—even with his ability to control the emotion, it seemed appropriate to let it happen. It already seemed like she was gone. His best lead didn't work. There was little else to do. "If you crash, I'll fly over and pummel Medio with asteroids." He couldn't think of anything better.

Nothing more convincing came to him as he awaited Felicity's reply.

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"Ha! I don't believe you for a second. You're not a destroyer of worlds."

"Listen . . . please stop and think about this. There'll be more Medios. More Anclajes. Take some more time to consider your decision—there's plenty of that. Please."

He waited.

Twenty-seven million kilometers closer to Spindown, Felicity's voice arrived. "I've thought about it. And I've made my decision. Medio's fate is sealed. It won't die this time."

"The neutron stars' orbital velocity has now exceeded ten percent the speed of light," reported *Zephyr*.

Feeling helpless, he looked at Spindown's hologram. The blurred disks now formed a torus, one growing redder on one side, while becoming bluer on the other. It was contracting. The rapid motion set up huge gravity waves, bleeding off the system's angular momentum, causing the two stars to fall together faster with each revolution. With the stars moving at a third the speed of light, the final orbit would last just a millisecond. The resulting explosion would throw part of the star's mass outward in two thick jets moving at an appreciable velocity of *c*. The spinning jets would collide with themselves and the disk matter, making huge shock waves and heating to millions of degrees. At the center would reside a single coalesced spheroid, flattened from its high rate of spin, or a black hole if too little mass was thrown by the impact. It'd be a collision that would, for a brief instant in time, generate more energy than all the Universe's suns. If he convinced Felicity not to crash.

The hill's angle lessened, and the trees thinned to a few squat, windswept needle-leafed varieties. "We're almost to the top," Trajan said, between labored breaths. His exhalations produced puffs of steam in the cool air.

"Borde looks beautiful!" Sage's voice was full of emotion.

He looked up at the large crescent of the outer moon, seeing swirling white storms, and deep blue seas. It stood out visibly in a sky that graded from pink to cobalt from a setting sun. "Yes, it does. Almost as beautiful as you."

She smiled at him. "Thank you." Her eyes carried a happy look.

He heard a rustling noise behind him and turned out of curiosity. It sounded like a large animal, and they'd just seen small ones so far. He saw the oval leaves of a dense crawling shrub underneath a wind sculpted tree.

Sage stepped next to him. Her elbow brushed his arm, leaving a warm, tingling sensation in its wake. "What is it?" she asked.

"I don't know, but something's in there." He stepped closer. Sage followed. Even with the distraction hiding in the shrub, he found her closeness enticing.

He saw motion under a wiry branch, and a brief glint. An eye. Four eyes. He could just make out the shape of the head, a spherical form with a flat face, and a slightly protruding beak for a mouth. Hair hung from its scalp, easily as long as Sage's; it touched the ground, the creature was so squat. *Is it lying down? Yes.*

Trajan pointed at the creature. "It's right there. Appears to be some kind of endoskeletal animal."

Sage glanced in the direction of his finger, her eyes opened wide in anticipation. "Oh, yes, I see it now."

The creature hooted several times, a loud sound that echoed off nearby granite cliffs.

"What's it doing?"

Trajan looked around. "I bet it has friends."

He was right. In a matter of seconds, several hairy heads poked up through the underbrush. He got a clear look at one as it walked between bushes, eying him. They had eight limbs spread between two "thoraxes." Four limbs on the hind-thorax were used for locomotion, while

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the fore-thorax was carried above the ground, limbs free. The front two of the free limbs were highly atrophied, and carried next to the head, while the other two were long and thin, with equally thin digits at their ends. The creature gripped a broken branch with those fingers.

"Murfle," mumbled Sage.

"Step back," said Trajan, though he wasn't too worried. He'd already contacted Persephone, and she had a satellite maser ready to fire if need be. Though he didn't really want that. He didn't enjoy killing, this was the natives' world, and these creatures had no idea what they were up against—about as innocent as anything could be.

Sage grabbed his arm firmly, and together they stepped back, moving up the gradual slope. Rocky soil crunched under their feet.

The strange animals froze and watched.

"I think things are going to be OK," Trajan whispered. "Just need to give them some room."

"Yes."

A light breeze picked up, one that fluttered Sage's long hair and played it across his back. The gentle patter was alluring.

When they had stepped back about twenty meters, the creature in the shrub stood up. It carried something.

"A baby!" said Sage in a loud whisper, apparently unable to control her excitement.

Trajan decided he'd have to try free emotions again one day.

"How pretty," Sage continued as she watched the mother and child with an open-mouthed smile.

"Ah, protecting their young. In a group and using crude tools."

"Yes, Trajan, presentients."

He looked at her.

She grinned. "I asked Persephone as we were backing away."

"How you shunned my use of the satellite information!" he chided.

She giggled. "Sometimes I can't help myself."

"So, what else did you learn?"

"A robot paleosurvey has revealed that they're part of a class of animals that has been the dominant terrestrial megafauna for the last hundred and forty million years. Considering their brain size and tool-using capability, the best estimates put them at the equivalent of what our species was some ten million years before the advent of civilization. Maybe about the time of *Dryopithecus*."

Holding her baby tightly in her long forelimbs, the mother leaped out of the shrubs and pattered downhill. She mixed with the group, and, after a couple of hoots, they faded from sight.

"We used to care for our babies that way," Sage mused. "Carrying them with us when we had to travel, exposed to the elements. So long ago."

Trajan nodded. He wondered what it would be like to have been raised at a time when just about every turn of the trail, or change of the weather, posed a threat. Most children didn't survive their first year. That kind of childhood was something he would never experience, even with millions of years of life. You only get born and grow up once—unless you chose to have your memories separated from you for a time while you "grew up" again, but that wasn't quite the same once you had your old memories given back.

"Maybe in several million years," Trajan said, thinking of *Homo sapiens'* life-extending technological progress, "these creatures will have their own budding cities, and space travel." *Giving everyone born an opportunity to live a full life*, he said to himself.

Sage grinned at the idea. "Yes! Look at what they have to fly to!" She pointed to Borde, which stood out starkly in a rapidly darkening sky. Stars were beginning to show, and a couple of distant planets. "With that kind of incentive, I think they'd move offworld quickly." She looked into his eyes and said, "What a wonderful encounter!"

"Indeed." Maybe it was the cheerful

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gleam in her eyes, or the enticing smile on her lips. He nevertheless kissed her.

After a brief hesitation, she returned the favor, sliding her tongue past his lips. A lovely, fiery sensation grew in his chest, and moved down into other regions of his body.

Sage pulled away. Her face had a childish glow. "C'mon! Let's find someplace comfortable at the top." She grabbed his hand and pulled him uphill at a run.

"Felicity's adjusting her course," said *Zephyr*. "She's timing the collision to strike the neutron star as it moves away from her, to give it a quick shove."

Ashley watched her ship's hologram. *What else was there to do?*

"Fifty seconds to impact."

Ashley leaped out of his seat. There was just enough time for one last message to reach her. "No! Don't do this! Please . . . Sage." Maybe the old name would remind her of that special time they had together so long ago, and convince her not to crash.

After a pause that was too short for her to have heard his plea, Felicity said, "I appreciate what you're trying to do, Trajan. We had fun together. Now . . . it's time for that to end."

Was she crying?

Felicity continued, "You talk about change, Ashley. Its permanence. Think about what you're doing."

"But—" He stopped, knowing that she wouldn't be around long enough to hear the message.

"I love y—"

"Impact," said *Zephyr* calmly.

There was an instant flash—dimmed by *Zephyr*, who opaqued the dome. Then he was past the suns, moving away at 0.99+*c*, leaving behind a stellar eruption that would be seen by unaided eyes for hundreds of light years around. Probably even by Medio's sentients.

He fell to his knees, feeling weak, sick to his stomach, shedding tears, things he hadn't experienced in a long, long time, but things that seemed right to let happen. Memories welled up. Felicity's mysterious frown as she stared at Anclaje's moons. Her talking quietly about Rebirth. Saying "Murfle" in frustration as he was about to cut away the stinging shrub. The cheerful, glowing look on her face after he had kissed her for the first time.

Zephyr reported, "The calculation's rough now, but the stricken star seems to have been shifted into a highly elliptical orbit, one that will last for several million years."

Ashley rubbed the tears from his eyes and mumbled, "Take me back to Medio."

"Sending commands to alter course. The first in a series of mass beams that can shove us in the right direction is thirty-eight light years away. We'll arrive in several millennia, Medio's frame of reference."

He nodded, unable to vocally respond to the words. All he wanted to do was remember the person he loved. . . .

A cool wind shuffled fingery tree branches, making them wave across a dense peppering of stars that glittered overhead. The breeze carried a sharp pine-like scent. Bordo's crescent hung low and looked smaller than it had previously, having drifted away in its slower orbit.

The gentle heat from a portable mattress placed on the rocky peak kept Trajan comfortable. Nevertheless, he held Sage close, savoring her naked warmth.

"Now, about that question I asked when we first met."

She looked into his eyes. "Oh, about the moons' meaning to me." She glanced away, and he saw that tiny intriguing frown on her lips again. She took a deep breath.

"These moons . . . they remind me . . ." she let the words trail off as she stared at the star filled sky.

An animal called from a nearby tree. The somber song reminded him of distant, gray, rainy lands.

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"Of?" he urged.

"I heard about a planet," Sage said slowly, almost sadly, "a world called Bode."

"The one that had those incredibly fast seasons?"

"Yes. It's dead now. Its orbit decayed, and now Bode is a sun-baked rock. Nothing seems to last, does it?"

He shook his head.

"And another world," she said, continuing her sad tone, "Goliath, where ecosystems dependent on meteor impacts once lived. That world's dead too. Finally had a large enough strike to boil its oceans."

"I met someone who witnessed several of the larger impacts on Goliath. Said he was there for fifteen million years. Sorry to see the world go, but that's how Nature works. Constant change."

"I don't like it."

"Ah, you're worried that these moons will fade one day, like those other worlds."

She nodded solemnly.

"I'm sure that when the dinosaurs roamed Earth's surface, it was a beautiful place. Then Nature took that away. Each instant in time is like a note to a song, I guess, with all the worlds making one grand concert."

Sage nodded. She didn't look very happy. "I don't like it when a song ends."

"It hasn't ended. Nature will make more worlds. Surely there's another Goliath out there somewhere, and another Bode. Maybe not in this galaxy, but elsewhere."

She stared into his eyes. "Nature won't make worlds forever. That changes too."

He rolled onto his side and propped his head on his hand, elbow to ground. Giving her a serious look, he said, "But that's a long long ways away, even for us."

"I don't know. When I was young, thirty million years seemed like a long time. I couldn't comprehend people living for so long, even with them around me. Now . . ."

He nodded, and said, "Now we've lived longer than most species do, and are faced with the undeniable truth that everything changes, no matter how grand."

She looked at him. "How can you accept it so easily? Isn't there anything you want to last forever?"

He smiled at her. "Yes. This time I've had with you."

She grinned. "Be serious!"

"I am."

Medio's sentients had just begun to study their neighboring worlds with crude telescopes when Ashley arrived. He locked into a polar orbit around Anclaje, a position that gave him a good vantage in which to watch the Medions. With their primitive technology, they wouldn't be able to spot him for some time, and until then, he wanted to be close.

The Medions were going to fly to the stars. If an incoming asteroid threatened their world, he'd deflect it. If their sun produced a vast flare, he'd block it. If the Medions decided to nuke themselves back into the stick age, he'd stop it. His versatile fleet of self-replicating robots, some as small as a gnat, would see to all those problems and many more.

The Medions would never know that he had intervened. They were going to learn about the Universe and think they had done it all on their own. And for the most part, that assumption would be true.

He was going to watch the Medions grow, grow into a race every bit as grand as humanity. Just as Felicity would have done. ■

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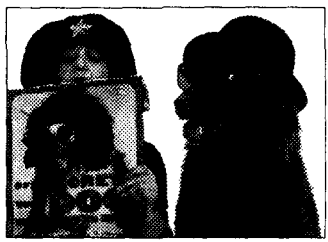

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Dr. Paul Levinson

The Book on the Book:

A Prognosis for the Page in the Digital Age

The book enjoys a position of unique authority in our world. Judges routinely "throw the book" at the worst criminals; professionals ranging from police to scientists conduct investigations "by the book"; when we receive the established wisdom on any subject, we get "the book" on that; and, of course, for the religiously inclined, we have the ultimate authority in the Good Book.

None of this is surprising, or unearned. As a portable yet permanent packet of highly abstract, precisely presented information, the book has been unequalled throughout most of its history. Its introduction in Europe as a mass product of the printing press made possible the Protestant Reformation: what impact would Luther's urgings that people should read the Bible for themselves have had without Bibles in everyone's hands? The book defeated the Church's attempt to quash the Scientific Revolution: Galileo's recantation in the court of Rome meant nothing with his words already in the hands and minds of the growing body of Europe's readers, courtesy of the book. The Age of Discovery was ignited via books—best sellers in their day—with reports of Columbus's voyage, reports in black-and-white which people could see again and again, and take seriously, unlike the Norse oral sagas of their voyages to the New World 500 years earlier, no more substantive than rumors whispered in the midnight winds. National identities were crystallized in books that allowed people to read—not just talk—in vernaculars for the first time. Public education emerged, capitalism was kindled, the list goes on and on.

The process was mutually catalytic. The Roman Catholic Church weakened by the Protestant Reformation was a less effective opponent of the Scientific Revolution. The new availability of books in all areas created more pressure for effective public education, whose prime task was soon seen as teaching children how to read. Each increase in readership

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intensified the process on all levels. The result was our modern world.

But books were never without their limitations as vehicles of knowledge. How many books can be stored in a given library? What hours is this library open? How many books can one carry home from the library? What happens when the book you desperately need is being read by someone else? Bookstores may have more than one copy of a given book available for sale, but their selection is far smaller than the library's, and their books usually stay on the shelves a far shorter time.

Fortunately, the science and culture that the book has given rise to have created a technology that addresses just such limitations: text, digitally encoded, stored online, can be accessed 24 hours a day from any place in the world. One person reading an electronic text precludes no one else reading that very same text. Although online storage capacity certainly is not infinite, it is effectively limitless in comparison to the confines of physical bookstores and libraries.

In this article, we consider the future prospects of the venerable book in this new electronic milieu, a source of both competition and support for the book's position at the pinnacle of intellectual media. We will examine some principles of media evolution that I have developed over the years, and we will use them to disentangle the extent to which our attachment to books is based on real advantages in performance versus rosy nostalgia. We begin with some of the defects of books, and the physical properties from which they arise.

Drawbacks of the Tome

Information itself—as distinct from its conduits and containers—has no physical properties. Like a restless spirit, it adopts the features of what it inhabits. Its physical characteristics reside in the means of its conveyance. Words spoken in the air move at the speed of sound; those same words electronically encoded and broadcast on electromagnetic carrier waves travel at the speed of light. When they are written on paper, published in newspapers, magazines, and books, they move at a pace far slower: the speed of everyday transportation. The roads of ancient Rome were thus as much a communications network as a transport system.

The irony is that the book in its day traveled faster and farther than any other medium. Unlike carvings on walls and monuments, the book could be moved; unlike papyrus and parchment, books made of paper pages could be moved great distances without fear of disintegration. But compared to the lightness and speed of electricity, even the thinnest piece of paper seems a cumbersome thing.

The quickness of electricity engenders not only speed of transport, but unprecedented ease of copying. That is why a text electronically encoded can be read by one or a million people at the same time, assuming they have appropriate computer equipment: a new copy is generated at the source, perhaps on a central computer half a world away, each time a reader receives a document on his or her screen. In contrast, the poor book must be printed anew for each copy. And much as computers have streamlined the paper printing process, in the end the speed of book production is hostage to its slowest link. Books take time—not only to write, which is at the author's discretion, not only to read, which is part of the pleasure they convey, and in the reader's control—but to be moved and to be produced, which pleases no one.

And yet, for all of these drawbacks of the book in our electronic age, people retain a great affection for them, as well as their cousins the magazine and the newspaper. I would wager that very few if any of you currently reading this article in *Analog* would prefer it scrolling on your computer screen. Part of that flows from the content of this article—

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nothing in it is so urgent that you would have gained much from its instant delivery a week, a month, or a year ago. But part of this also flows from real functional advantages of books and print on paper, regardless of what its words say. And part of our affection for books may stem from a nostalgic attachment we retain for products of the press, regardless not only of their content but their functional advantages and disadvantages.

In the next sections, we attempt to sort out some of these intertwining factors.

Lessons in the Pen and the Watch

When I was a kid growing up in the 1950s, the instruments of personal penmanship were a subject of some debate in my house. My father, an attorney, was a firm believer in the fountain pen, for all but the most trivial writing. He gave me a fountain pen for my tenth birthday. But I was already a subscriber to the upstart ballpoint, which I saw as superior to the fountain pen on nearly all fronts: ballpoints didn't smear, rarely bled in your shirt pocket, and were much easier to "refill." On the fountain pen's behalf, it perhaps permitted more personality, more flair, in its inscriptions. But my father's passion for the fountain pen was for the most part a brief for the medium he had grown up with—comfort with the device he had known and relied upon all of his life, rather than the result of a logical analysis of its benefits and shortcomings (which was otherwise his strong suit). Today, the fountain pen of course yet has its devotees, but they are few in comparison to the legion users of the ballpoint and its progeny, persuaded by the undeniable convenience of the fountain pen's successors. As we near the end of this century, the fountain pen thrives mainly in the realms of nostalgia and deliberate attempts to be different from the pack. (Slowly dwindling attachment to traditional, less efficient instruments of writing is apparently nothing new. Beckmann observed in his *History of Inventions*, 1846, p. 411, that "Notwithstanding the great advantage which quills have over reeds for writing, the latter however seem to have continued long in use even with the former.")

Several decades after the advent of the ballpoint, another medium of the hand—or, more precisely, the wrist—made its debut. This one was digital, not in the manual sense of the pen, but in the mathematical sense that the word has come to typify so much that pertains to computers, including the subtitle of this very article. (Actually, both uses of "digital" stem from the same hand: the earliest form of mathematics was counting on one's fingers.) The digital watch displayed the time in numbers that were immediately comprehensible to even young children, in contrast to the positions of the hands of the analog timepiece, whose meaning had to be learned. Why contend with big hands, little hands, second hands, when the time could be instantly and exactly had with a glance at the numbers on a watch face?

And yet . . . unlike the ballpoint's triumph over the fountain pen, the digital watch has failed to vanquish the analog. Indeed, to the contrary, the analog watch is more popular than ever: an informal survey of my undergraduate class at Hofstra University (Hempstead, NY) just last week revealed more than 90 percent of the students sporting analog watches. What, other than the eminent commendability of the name "analog," is responsible for this turn of events?

The answer is that the analog watch does things that the digital watch cannot—and, moreover, does things that are of significant interest and value to people. The analog watch tells us not just the present time, but where it came from and where it is going. Unlike the flat display of numbers on the digital watch, the hands on the analog face give us a sense of past and future—not just a snapshot of the present, but a gestalt of the process of time, of where we were and where we may be. If, as cognitive anthropologist Alexander Marshack ob-

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serves, humans are a narrative species, then the analog watch speaks to our specieshood in this quiet way that the digital watch does not.

Here we encounter a most fundamental principle of media evolution: a medium will survive to the extent that it performs a task (i) important to humans (ii) that no other media can perform, or perform as well. In the Darwinian evolution of media, humans are both the generators of new "organisms," and their external "selecting" environment. I first noticed and detailed this human "natural" selection of media in my doctoral dissertation, "Human Replay: A Theory of the Evolution of Media" (New York University, 1979), and develop it further in my most recent book, *The Soft Edge: A Natural History and Future of the Information Revolution* (Routledge, 1997). Silent movies, a sight-only medium, were eradicated by sight-and-sound "talkies" even more quickly than the fountain pen was replaced by the ballpoint; in contrast, radio, a sound-only medium, not only survived the massive competition of sight-and-sound television, but is today the most profitable medium in America, dollar spent for dollar earned.

Why did uni-sensory radio do so well in the face of its multi-sensory competition, whereas uni-sensory silent movies did not? The answer resides in the nature of the sense each medium played to, and the role of that sense in human life. The world grows dark every night but never really silent, we can easily close our eyes to block out sight but we have no earlids: hearing without seeing is a fundamental mode of human communication, one which keeps us in touch with the world in the dark, whereas seeing without hearing as company is alien to our biological being. Radio thrives in a television age because it inadvertently fulfills an eavesdropping niche, a human mode of communication, in residence long before the invention of either medium—hardwired, in fact, into our very sensory apparatus.

We can now put our question about the future of books in the digital age more precisely: will they go the way of silent movies and the fountain pen, relegated to the realm of deliberate artistic statement and nostalgia, or emerge from the information revolution proud, unbending, resplendent, like the analog watch and radio?

As we'll see below, the answer will likely be a little of both.

Fleeting Phases

In gauging the survival prospects of any technology, including books, we also need to distinguish between features that are inherent and irreducible in the medium, and features that are transitory. The first kind of characteristic is so fundamental to the device that, were it changed, we would have by any reasonable designation a new device. The second could be changed, or we could imagine changing, without any injury to the underlying device itself. A horse-drawn vehicle with new kinds of wheels, even a horse bred for greater speed and/or strength, is a still a horse-and-carriage; a horseless carriage, powered by a combustible engine, is no longer a horse-and-carriage at all—it is a car. Clearly, any worthwhile assessment of a medium's survivability in terms of how well it performs human functions must relate to its intrinsic, defining characteristics.

But sometimes, in the heat of the present, these are not so easy to see. An objection often made against the ultimate success of books on screens is that you can't cuddle up with a computer—can't read it in the bathtub. Aside from the the fact that books, magazines, and newspapers are no particular joy to read in the bathtub either—would this copy of *Analog* you are now reading benefit from a good soapy soak?—the objection misses the point that there is nothing inherent in the screen that makes it "uncuddleable." Surely, if we value the warmth of cloth and paper, we could

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devise computer screens mounted in cloth and paper, that felt the same against our skin and laps as the well-worn book. That we do not have these right now is merely an indication that the medium of the electronic book is still in its infancy, in a caterpillar stage that yet reflects its clumsy cathode-ray tube origins.

And the same applies to the traditional book—not every aspect of its current configuration and delivery system is intrinsic and essential to its continued existence as we now know and love it. "On-demand" instant production facilities have long been proposed, and are already in operation in some sites, where texts are transmitted electronically from a central computer storage source and immediately printed and bound. In theory, there could come a time when everyone has such an immediate book-making facility in their home—much as many of us now have fax machines hooked up to our computers and phones. Such a facility would allow the book to compete on an equal footing with text on the screen as far as immediate access is concerned: one copy of the text, on a central computer source, could be transmitted to the same unlimited number of people as an electronic text, and at the same speed of light.

With the delivery thus equalized, what enduring advantages would remain for electronic over paper text, and vice versa?

The Enduring Difference of Hypertext

A prime principle of technologies and their impact explored in depth by theorists such as Marshall McLuhan is that their most profound consequences are unintended. Bell invented the telephone in pursuit of a hearing aid for his wife; Edison's first thoughts about the phonograph were that it would quickly become a universal telephone answering machine; and Marconi's notion of the "wireless" was a telegraph or telephone without wires, an interpersonal two-way mode of communication rather than the simultaneous mass medium of radio that his invention brought into being. Online computer networks were first developed by the US military in the late 1960s as a way of more efficiently moving words. A quite unintended consequence of this was that words electronically encoded could not only be moved quickly, but could be linked to other words, instantly, provided they too were encoded on a connected electronic network. This unintended consequence is, of course, known as hypertext. And it may be the one advantage of electronic text that cannot be provided by books, however quickly they may be disseminated and assembled on the spot. "Clicking" on a word printed on a piece of paper, after all, goes nowhere.

Actually, hypertext had been predicted by Vannevar Bush in his famous "As We May Think" article about a "memex" device published in *The Atlantic Monthly* back in 1945, and extensively mapped out as a hypothetical possibility by Theodor Nelson in the 1960s in his "Xanadu" work. Indeed, the rudiments of hypertext can be found in the references and footnotes that adorn most scholarly texts printed on paper, including this one. If you were moved, after reading the first sentence in this paragraph, to seek out and read Vannevar Bush's 1945 article for yourself, you would be engaging in a manual, offline kind of hypertext—except rather than your fingers doing the walking (to invoke that old but still apt line from advertisements for the telephone "Yellow Pages"), you would be literally doing the walking, or driving, likely to your closest library, unless you had access to the Web. Other examples of hypertext ahead of its time would be Talmudic commentaries in the margins of written documents, which invite readers to follow diverging threads of argument (these could be considered a species of footnote), or Isaac Asimov's *Foundation*

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series, the novels of which can be read in order either of their publication, or in which the events take place in the stories. In each of these cases, readers rather than authors are determining the proximate sequences of texts—whether to proceed from the end of paragraph A to paragraph B, or to a new paragraph in a new book altogether—and therein sowing the seeds of hypertext.

Thus, although the Web and its hypertext connections and its first readily usable browsers like the aptly named Mosaic took nearly three decades to emerge after the origins of the Internet for different purposes in the 1960s, the roots of hypertext—the human yearning for connections that exceed the page at hand—have long been with us. And the electronic connection made all the difference in fulfillment of this need. Nothing short of a complete electronic milieu can work effectively for hypertext—not even the hybrid technology of texts electronically conveyed yet produced as books right on the spot. Yes, we could "click" on Vannevar Bush's article and have it rapidly printed for us on paper. But what happens when we wish to further study people and ,books referenced in *that* article—these include Leibnitz, Babbage, Mathew Brady, and the *Encyclopedia Britannica*—and then pursue references in those subsequent books, and so forth? Even were our immediate book-production technology up to such a task, we would soon be drowning in paper. We could slow the rising tide by producing just those pages in the books that seemed most likely to slake our interest. But such a strategy would reduce the possibility of discovering information in an unexpected place which is one of the glories of hypertext. And, besides, we would eventually drown in single sheets of paper as surely as in complete books. The utter intangibility of electrons behind a screen changes all of that. A screen, unless and until it breaks or fails, can be "refreshed" to display as many texts as wanted. There are of course limits to how many hypertext links any computer can hold in its memory, and the speed with which any text can be delivered electronically is modulated by the quality of phone lines, capacity of modems, and all sorts of external factors. But these, again, are examples of transitory limitations: modems in most homes today operate at 28,800 bits-per-second speed, in contrast to the 300 bits-per-second speed of the early 1980s. And new ISDN and cable-phone technologies are already sending data at better than 100,000 bits-per-second. In the world of instant connectivity, in realms in which the association of one text to another is the goal, online communication is the undisputed king. Even electricity, of course, cannot compare to the speed of our internal, imaginative, mental connection of one thought to another. But electrons and light do a lot better than their rivals. When it comes to hypertext, books just can't compete, paper doesn't compute.

But if the prognosis for books and paper as hypertext conduits is stark—if we can expect them to sink like stones in the multiply-connected data streams of the 21st century—does this mean that they have no enduring role as vehicles of information at all?

In our concluding section, we will see that the enduring role of books in the digital age may be just that: as repositories for information that we most want to endure.

Books as Centers

Giordano Bruno, as is well known, was burned at the stake in 1600 for his heresy that the Earth was not the center of the Universe; whereas Galileo was simply threatened for his. Aside from Bruno's refusal to recant, and the fact that as a monk his betrayal of Church teaching was all the more galling to the Church, his heresy was also far more profound than Galileo's. To support the Copernican theory that the Sun rather than the Earth was the center of the

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Solar System, as Galileo did, was bad enough. But Bruno held that even the Sun was the center of nothing—that the Universe, in fact, had no centers at all.

McLuhan, picking up on this radical notion three and a half centuries after Bruno's execution, observed that electronic media create a world whose centers are nowhere and margins are everywhere. If a radio signal is broadcast in a 300-mile radius, everyone within that range is equidistant from that broadcast—the radio receiver 10 miles from the "center" is no closer, effectively, to the origin of that broadcast than the receiver situated 100 miles away. And if that same radio or television signal is relayed by "booster" transmitters all over the country, or via satellites all over the world, then the "centerless" circle grows even larger.

Text electronically conveyed in a hypertext Web environment completes this decentralization process. Broadcasts may be without centers in terms of who receives them, but they nonetheless have discernible and economically significant points of origin in terms of who produces them. Indeed, they are classic examples of mass media, or technologies that deliver one message to many people. In contrast, the Web permits many people to distribute many messages to many people. A reader in pursuit of a hypertext trail—a trail in large part of the reader's own making, as the reader decides whether to click on McLuhan, Bruno, or Galileo in a text such as this—will encounter so many points of origin as to render the whole notion of origin, as well as center, somewhat moot. It is more than poetic conceit to muse that the constellation of ideas in an online hypertext world bears a great resemblance to the stars ashine in Bruno's centerless Universe.

But is there no remaining human hunger for a place to call home, a reliable location for our favorite ideas to reside? The Church was at its worst when it killed Bruno and threatened Galileo, but that does not mean it was wrong in its recognition of the human craving for a center, preferably one that could be counted on, and was close at hand. What the Church missed, of course, is that humans could have their centers—spiritual as well as physical—even in a centerless Universe.

Books might well continue to serve this purpose for ideas and information in a hypertext world. The very speed with which new operating systems, formatting codes, computer programs of all sorts are evolving threatens at any instant to render an older code unreadable on a current machine. I use an ancient 286 with an external 5 and 1/4 inch drive and an old program called "Uniform" when I need to read one of the thousands of files I saved in CP/M in the early 1980s—yes, I know, I should have transferred them to DOS a long time ago, but who has the time?—and who knows how much longer this jerrybuilt system will work for me. In contrast, my books are as reliably readable as the sunrise—indeed, as an additional benefit, they require no source of energy other than sunlight, or electric lighting already ubiquitous in our culture. Books thus come in a "format" as endurable as the human intellect itself, and with batteries always included. One day we may have, computers with as stable and universal a code, and which operate on sunshine. In this sense, the current advantage of books as "off the shelf" reading machines may be transitory. But the transition may well take some time—and seems unlikely to touch an even deeper sense in which books give us a sense of center.

Although computers can usually be counted upon, and can be as close by as books, there is no doubt that once we are on the computer—once we are online—we quickly lose a sense of physical location, of "rootedness." This is, in part, why the Web "surfing" metaphor caught on so quickly. But the book, likely and precisely because its pages always

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display the same words, provides this sense of location, and the commensurate feelings of comfort and security—an unbeatable combination of logos and locus.

So, does this mean the book will survive?

As a medium for the transmission of information, as a vehicle for the connection of one text to another, as a mode of transport across and throughout the intellectual landscape—likely not. Or, if the book does survive in this mode, it will be only in the manner of the silent movie and the fountain pen.

But as a place to pause, to come back to, to be there for us whenever our minds wish to venture into just that area, the book and its paper relatives are far more effective than the computer screen and its ever-changing letters.

True, we could develop a computer screen of whatever size whose letters never changed.

But then it would just be another kind of book.■

Further Reading

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Correction and Apology

The cover of our March 1998 issue was mistakenly attributed to Joel Shabram. It should have been credited to Vincent di Fate. We extend our apologies to both artists and ask all readers to note the correction.

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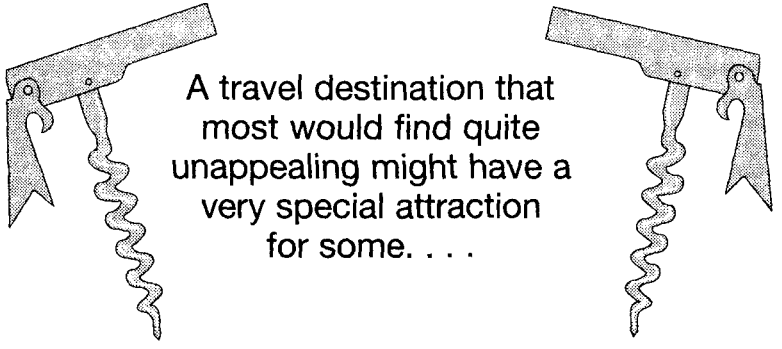
Michael A. Burstein

COSMIC CORKSCREW



Stasis felt unreal.

Dr. Scheihagen had warned me about that when I volunteered for this mission. "Remember, we don't know what it'll be like for you inside," he said in his German accent. "We've never sent a human so far back before."

Scheihagen himself had been the volunteer for the first few experiments, but he had only gone back in time on the scale of hours, not years. So he was little equipped to prepare me for my experience.

Even now, I can't describe it. How does one describe the passage of imaginary time in a box of Stasis, of timelessness? I felt frozen in time, while events passed around me in a blur of color. Throughout, I worried that I might get trapped in Stasis, and never emerge into normal time again. But I had been willing to take the risk for this literary mission of the utmost importance.

Finally, after an eternity of nothing, the Chronobox and I materialized in a small, isolated alleyway. I jumped out of the Chronobox, gulped down a few breaths of air, and closed the door. The sunlight passed through the glass cubicle, rendering it almost invisible. Only once I felt safely back in normal time did I check my wrist chronometer.

Its digital display of the date read 06:20:38. Monday, June 20, 1938. Afternoon.

Perfect. I had managed to reprogram the Chronobox right under Scheihagen's nose.

Scheihagen had warned me about it when he set up the controls.

"Remember our agreement," he had said to me. "I'm sending you back on June 23, when the story has already been rejected, so there's no chance of interference with the main event. You make one copy of the story, then get back into the Chronobox and come home. Do not interact with anyone, most of all, with him. *Ist das klar?*"

I nodded my agreement, not bothering to point out to Scheihagen that one

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of our subject's own short stories showed a timeline changing over just such a mission, even after the original work in question had been rejected. After all, the last thing I wanted to do was give Scheihagen a reason to suspect me.

Then, while his back was turned and he fiddled with the last few controls, I used the wrist chronometer—which was much more than a simple watch—to reprogram the date of arrival. I had to time this perfectly, making the change before Scheihagen sent me back, but not early enough in the launch sequence for him to notice.

Why did I do this? Because, despite Scheihagen's warnings, I wanted to make contact with the subject. When he was alive, whenever I had met him, I had always been a fan; by the time I had made a name for myself in his field, he was long gone. I wanted to meet him right at the start of his career, and as far as I was concerned, that beginning was right after he finished writing his first story.

I looked back at the Chronobox, then checked my clothing and patted my pockets. I was dressed in a jacket, tie, and overcoat, perfect to blend in with the natives of this era. In my pockets I had my scanner and my disorienter. The scanner was vital to my mission; the disorienter was for repairing the past in case I made a mistake. Feeling confident, I turned around the corner and walked to my destination: the candy store at 174 Windsor Place in the Park Slope section of Brooklyn.

I had memorized the route in the future, and here in the past I found my way quite easily. The candy store stood in the middle of the block. A newspaper rack sat outside, with the day's papers and more popular magazines of the era prominently displayed. I pushed the door open and went in.

The details of this store were important to me, and I wanted to take in everything I saw as perfectly as possible, so I could remember it once I had left. The first thing I noticed was that the store was broader than it was deep. To the left, near the wall, I saw a cigar counter and a cash register. Behind the register were vertical slots against the walls, crammed with cigarette packets. At right angles to the cigar counter was a candy counter, with three rows of penny candies (penny!) and one row of nickel candies. The sweet smell of the cigars wafted through the store, permeating it with a pleasant, musty odor.

On the right side of the store was a soda fountain, and right along with it a refrigerator, containers of syrup, electric stirrers, faucets for carbonated water, and a sink. Four stools sat below it, currently empty. I was the only customer in the store.

On the right wall was a magazine stand. Next to it, a rotary telephone, and a table with four chairs. And then, coming around to the right side of the door, an ice container.

And back behind the cigarette counter stood a young man, only 18 years old, wearing glasses and showing an impossible grin. He looked at me, and with an unmistakable Brooklyn accent, said, "May I help you?"

I was in the right place, the right time. Standing behind the counter was the young Isaac Asimov.

I told him I was just looking, which seemed to strike him as odd; I guess most people in this era came into a candy store intent on one or two particular items. But he seemed to relax when I headed to the magazine stand and began studying the titles.

I had to take a few deep breaths just to calm myself down. Part of me was worried that at any moment, Scheihagen might appear to drag me back to the future, or perhaps the universe might collapse around me for having already violated his protocols by slightly altering the timeline with my brief contact. But most of me was feeling simple awe at being in the presence of one of the greatest writers of the twentieth century.

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I considered my next move. I really wanted a chance to talk more with the young Asimov, and it seemed to me that I no longer had to worry about disrupting the timeline. After all, I had already made contact, and I was still here. I convinced myself that it meant that my actions were harmless.

But that still left one question: how could I get him to talk to me? What could I do to get him to want to strike up a conversation with just another anonymous customer?

And then my eyes, wandering over the titles of the magazines, fell upon the current issue—that is, June 1938—of *Astounding Science-Fiction*. It was perfect; the obvious way to hit it off with the young Isaac Asimov. I studied it for a moment as I gathered my resolve. The cover illustration was a painting of Mars as if seen from Deimos. Quite good, given the fact that no one in 1938 had set foot on the Moon, much less on Mars. Of course, even in my time, the three human figures standing on the Martian moon's surface and their silver cigar-shaped spacecraft were still the province of science fiction, not of science fact.

I grabbed a copy and brought it over to the counter. Asimov had been staring into space; now he came out of his reverie and prepared to take money from me.

He looked down at the magazine, then gave me a quizzical glance. "Pardon my asking," he said, "but you read science fiction?"

I nodded; I felt a lump in my throat and it took me a moment to find my voice. My ploy had worked. "Yes. Why?"

He looked around for a moment; we were still the only two in the store. "I do too. And I haven't met too many other readers of science fiction."

I thought for a moment; at this point in his life, Asimov was writing letters to the magazines, but he hadn't yet hooked up with the Futurians.

"Well," I replied with a smile, "I've been reading *Analog*—" oops "—I mean *Astounding*—for a while now."

"Really? What's your name? What do you do?"

"Um—" I didn't want to give him my real name. "Schwartz," I said after a moment of thought. "Joseph Schwartz. I'm a—a teacher."

"I'm Isaac Asimov. My family owns this store, but I'm a chemist." We shook hands.

"Dr. Asimov—" I began.

He laughed. "Doctor? Call me Isaac! I'm nowhere near to a Ph.D. yet."

I felt sheepish; I had just addressed him as I always had, whenever I had met him in his later life.

"Sorry, Isaac," I said, which felt strange. "Tell me, um, have you read this issue yet?"

"Have I!" He turned the issue around so the cover was right side up for him. "I finished this one a few days ago." His fingers traced the banner at the top of the cover which proudly boasted "THE LEGION OF TIME by Jack Williamson." His eyes were filled with enthusiasm. "I've been enjoying the Williamson serial. How do you suppose he's going to end it?"

"Um," I said. I had never read it. "I'm really not sure."

"Well, I think . . ." Asimov began, and he launched into a detailed plot, based on his own extrapolation of what he felt would come next.

When he finished, I said, "You know, that sounds pretty good. Have you ever thought of writing the stuff yourself?"

He looked away for a moment, then said, "Actually, I have."

I knew that, of course. "Really?"

He hesitated. "Yes. I just finished a story yesterday. My first."

"What's the title?" I asked.

"'Cosmic Corkscrew.'"

This was the pivotal moment. "May I see it?"

He got a wary look on his face. "What do you teach?"

"Physics," I said.

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His look changed to one of relief. "As long as it's not writing."

Isaac reached under the counter, and pulled out a sheaf of papers. With a slight tremble in his hand, he handed the manuscript over to me. I flipped through it eagerly. Years later, in his autobiography, Isaac himself had admitted that the story must have been utterly impossible.

And yet, as far as I and many others were concerned, it was the most valuable thing in the world.

"It's a time travel story," Isaac said as I flipped through it. "You see, I call it 'Cosmic Corkscrew' because—"

"—time is a helix," I murmured to myself, but a little too loudly.

"Oh, you saw that part already? I decided to use the neutrino as the explanation for time travel, since they haven't been discovered yet, only theorized."

I nodded my head, remembering comments he had made about this story in his autobiography. And then I made a blunder, but I couldn't help myself. "You know, you got it wrong," I said.

"What?"

"That isn't how time travel really works," I said, and then I clamped my mouth shut.

"What are you talking about?"

In for a penny, in for a pound, as they say. I had already started to tell him the truth; I might as well finish it. "Isaac, if there's anyone in 1938 who can believe my story, you can."

"What story?"

"I'm a time traveler. I've come back from the future for this." I lifted the manuscript.

Isaac looked around for a moment, then looked back at me. "This is a joke, right? Someone put you up to this?"

I sighed, and put the manuscript on the counter. "It's not a joke. You've been thinking about how to deliver this story to *Astounding*, and you're planning to talk with your father about it."

"How—"

"Tomorrow you're going to take the subway to the offices of *Astounding*, and meet with John W. Campbell, Jr. for the first time. He's going to take your manuscript, read it, and reject it. But you'll begin a working relationship with him that will change the face of science fiction."

"What are you—"

I didn't want to stop now. "'Cosmic Corkscrew' will disappear, Isaac. You'll let it get lost, and you'll bemoan the fact in a collection of your early works. You'll write about how many fans of yours regret its loss, and how you do too. You'll point out that there was no way you could have known how much people might have wanted to read the story in the future.

"But I'm from the future, and we know, Isaac. We want the story."

I gave him a moment to assimilate everything I had said. Then he shook his head. "I don't believe this."

"It's true. How could I know so much about your story, or what you're planning to do with it?"

"It's no secret that I read science fiction, or that I might want to write it. You could have guessed some of what you said, and made up the rest. I'm a scientist. You'll have to offer better proof if you want me to believe your story."

"Fair enough." I pulled back my left sleeve and showed him my wrist chronometer.

He studied the digital display intently, and lightly touched the molded metal and plastic of the device. I knew what he was thinking: could this device be a product of 1938 technology?

And the answer had to be no.

Finally, he looked up at me, his face slightly pale. "My word," he said. "You're telling the truth. You really are from the future."

I nodded. "Yes, I am."

"And I—I become a famous writer?"

"Yes, you do."

"And you've come back for—for me?"

I shook my head. "Not for you. For your manuscript." I pointed to where it lay on the counter "The future wants it."

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He shook his head. "I don't believe it. I mean, I do, but I don't."

I nodded. "I understand. But it is true. I'm here, and I need your manuscript." I pointed at it again.

He picked it up quickly. "I can't let you have it. It's my only copy."

"Oh, don't worry about that. I'm not going to take that particular copy. I've come prepared." From under my coat I pulled out my scanner, a thin rod just about nine inches long.

"What is that?"

"It's—" I paused. They didn't have photocopy machines in 1938, did they? Or xerography? "It's like carbon paper. Watch."

As I ran the scanner over each sheet of manuscript, it spit out an identical copy. I suppose I didn't have to bother with the hard copy, as the scanner stored a copy of anything it scanned in its memory, but I wanted to feel the manuscript in my own hands as I brought it to the future. When I was done, I had a pile of papers that matched Isaac's manuscript almost perfectly.

He whistled. "A device like that could change the world."

"It will. And it's because of people like you that such devices will be made."

I couldn't help myself. I really couldn't. I told Isaac all about how he would go to meet John W. Campbell, the editor of *Astounding*, at the offices of Street & Smith tomorrow. I told him how his friendship with Campbell would lead to a career as a full-time writer. I told him that his first published story, "Marooned Off Vesta," would appear in *Amazing* next March, and that his first sale to Campbell, a story he would call "Ad Astra" but which Campbell would change to "Trends," would appear in the July 1939 *Astounding*.

We talked, of space, and galaxies, and tesseracts, and time travel, and rockets to the Moon, and of all the dreams that were yet to be. I wanted to stay forever, but every millisecond I stayed increased the possibility of disrupting the timeline. Isaac noticed me glancing at my chronometer every so often, and after a while he got the idea.

"You need to leave, don't you?"

I nodded. "This is it, Isaac. I have to go now."

Isaac smiled at me. Then he got a worried look on his face. "What happens now? Do you erase my memory?"

"No," I lied. "Just—do me a favor. When you write your autobiography—"

"I'll leave you out of it, I promise."

"Good."

But he got a twinkle in his eye. "Although—you know, that gives me an idea for a story. What if I put something in print here in the past that can only be recognized in the future?"

I thought for moment. "It does sound like a good idea for a story, but don't start it until late 1953."

A second later, Isaac laughed. "I guess I do use the idea, then."

"Yes, but don't do it before then. Otherwise it'll be the end of—of everything."

He nodded, letting me know that he was aware of the dangers of disrupting the timeline. "Thanks for telling me about my future. It's nice to know that I'll succeed."

"You're welcome," I said sadly. "Farewell."

As I walked to the door to leave, I turned back to look at him one last time. He was already looking away, staring into space. I wanted both of us to be able to treasure this conversation forever, but I knew that I couldn't let that happen, despite his assurances. So I pulled the disorienter out of my pocket and fired it at him. It made no noise, displayed no light, but I knew it had worked. His face took on an air of bewilderment and confusion, and then readjusted to normal. I dashed out before he could notice me, and left him to dream the daydreams of the idle shopkeeper.

* * *

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I headed back to the alleyway where I had left the Chronobox, clutching the manuscript in my hands as I walked. I shook with fear over the possibility that I might have disrupted the timeline; but no, I was still here, meaning that my interference had been negligible.

The Chronobox was undisturbed, and the alleyway was as empty as before. All that I needed to do was enter the Chronobox, set the date for the present, and return home.

But I hesitated.

I wanted to stay here, in 1938. I knew what was about to happen: the golden age of science fiction. I could hang around, watch the greatest writers of the genre come of age. I could attend the first Worldcon, read the stories and novels as they first appeared, and own a collection of works to rival that of anyone. Living in the United States through World War II would be a small price to pay, as far as I was concerned.

I could be a part of it all. I would just have to make sure that I remained a small, insignificant member of science fiction fandom, so as not to disturb the future into which I would eventually be born.

I looked at the copy of "Cosmic Corkscrew" I held in my hand, and I looked at the Chronobox. I owed something to the future, I knew that, but I wanted something that was only available to me here in the past.

I knew what I had to do.

I gently placed the manuscript inside the Chronobox, closed the door, hit the button on my chronometer and punctured Stasis. Immediately, the manuscript disappeared and the Chronobox appeared empty. A moment later, the Chronobox itself vanished.

I turned on my heel and left the alleyway, readier than any other man in 1938 to face the future.

Except, perhaps, for Isaac Asimov.■

For my father Joel David Burstein (1929-1990)

Man has always been afraid of his urge to do more and to know more. His earliest myths attest to that fear: Adam and Eve, the Tower of Babel, Prometheus, Pandora, Icarus. But he is constitutionally unable to restrain himself.

— Samuel C. Florman

Antony was a pushover for Cleopatra. If there is any moral in this, or what happened to Caesar, it is that generals should keep away from beautiful women.

— Eric Temple Bell

There are plenty of instances where gifted amateurs have done and discovered things to the chagrin and redfacedness of the professionals.

— William F. Friedman

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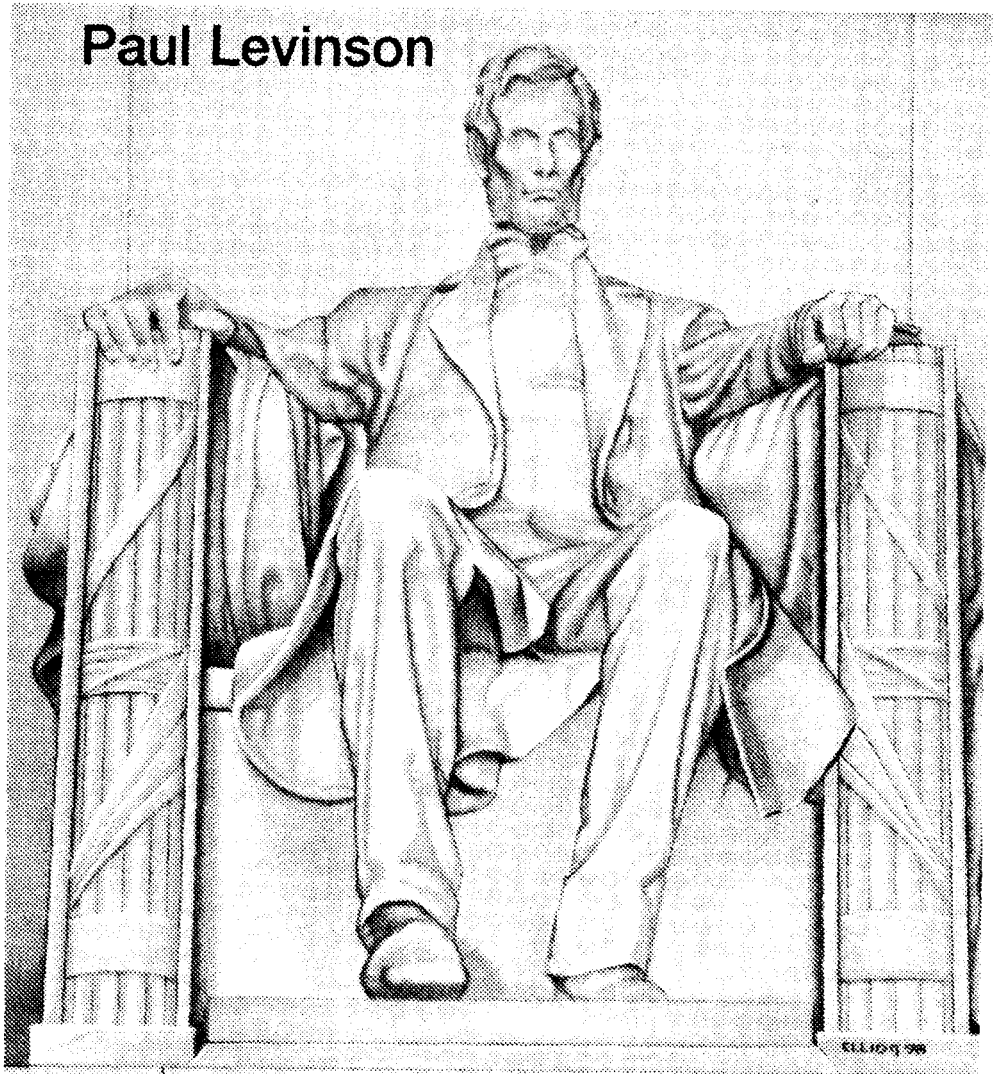
Paul Levinson



LITTLE DIFFERENCES

Sometimes, when brute force won't work, you have to be sneaky. . . .

Illustration by Darryl Elliott

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Dion was singing "Abraham, Martin, and John" on the radio.

Jeff was making breakfast.

When Dion got to the part about Bobby, Jeff took the egg he was about to crack and threw it against the wall. Then he did the same with another. Then he took the whole box and smashed it on the floor, and stomped on it for good measure.

He was still mopping up the mess and crying when Laura walked in a few minutes later.

"Honey! What's wrong?"

Jeff shook his head, said nothing. They'd been over this before. He had to steel himself against this kind of thing. He'd never make it to 1986 if he broke down every time he heard a song about an assassination he could have stopped. But there was something about that last verse—

Laura pulled him up into her arms, kissed his neck, drew his arms around her.

"I still have egg on my hands—"

"It's OK, baby," she said. "Shhh, it's OK." She kissed him again.

"It's just that last verse." Jeff said. "I don't think 'Abraham, Martin, and John' was originally written that way—with the verse about Bobby. They just tacked it on, after he was killed. That's why his name's not in the title. It's bad enough I was here when JFK and *now* Martin Luther King were murdered, and I did nothing—"

"You tried with JFK," she said. She stroked his head. "It wasn't your fault."

"I tried and I failed," Jeff said. "And now Bobby. If his name wasn't in the song at first, maybe he wasn't supposed to die. Maybe I, we, were supposed to save him. And I did nada—nothing!"

"We've got to stay focused on the Challenger," Laura said.

"I know," Jeff replied.

"That's the key to all of this," she continued. "If we don't stop it from crashing into that schoolhouse in Florida and killing all of those kids . . ."

Jeff knew she was right. Nothing else mattered compared to changing that reality from his timeline to Laura's, from a world in which the space program died a final death to one in which just the astronauts died in the Challenger, and the space program limped along and took wing again in the following decades. Still . . .

"It's just—this has been one lousy year, event-wise," Jeff said. He looked at the calendar on the refrigerator. It was on its last page—December, 1968. He'd be glad to pull it down and throw it in the trash with the rest of the year.

"Well, at least we'll have Apollo 8 circling the moon this Christmas, and Armstrong and Aldrin on the moon next year," Laura said.

"Yeah," Jeff said, "and Nixon in office. He'll throttle the Apollo program barely out of its cradle, and then give the Shuttle such poor funding that it's amazing it didn't blow up long before 1986."

"We'll just have to do something about that, then, won't we," Laura said.

Jeff hugged her, eggy hands and all, and thought, yeah, and maybe we can still do more than that too.

"God, these hamburgers are gonna kill me, but I love 'em." Sam McKenna smiled across the table at Jeff, and made a stab at wiping some of the grease off of his chin.

"Part of the charm of the South Campus Cafeteria," Jeff said. "Lousy food, cold spilled coffee on your table, a good shot at getting boiling-hot coffee on your hands. But hey, there's always a chance of picking up a juicy tidbit of conversation about another professor, maybe even about yourself, from unknowing students at a nearby table."

Sam chuckled and eyed the table next to them. "Not likely," he said. "They seem to be talking about dead Greek philosophers. I don't think any of them have tenure here."

"Well, at least we know they didn't die of South Campus hamburgers," Jeff

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said. "They probably aren't as bad for you as you think, anyway. There are dozens of cholesterols—"

"I don't wanna hear about cholesterol," Sam said and waved Jeff off. "Let's get back to what we were talking about—the space program."

Just as well, Jeff thought. Now that he was finally in line for a tenured position himself in the Sociology Department, there was no point jeopardizing it by dropping too many hints about a future only he could know. It was enough that he was discussing the space program with Sam—the sharpest professor in the Political Science Department, and someone Jeff had become quite close to in the past year.

"I think you're way off in your concerns," Sam continued. "Politicians are crazy about space—everyone loves it. Hell, LBJ sent framed photos of the earthrise—the shot taken by Apollo 8—to heads of state around the world, including Ho Chi Minh!"

"Johnson's out of office next week," Jeff said.

"You think Nixon's going to risk hurting the space program with the Vietnam War on his head? Scuttle the only bright thing he's got going for the American image these days?"

I know he is, Jeff thought. Not that the Democrats weren't responsible too. He'd studied Mondale's 1969 speech in Congress, to be delivered just a few months after Apollo 11. He'd gone over it and the entire Congressional record leading to the Challenger very carefully before he'd left—that was, what, almost six years ago, before he'd come here from 2084 in the Thorne? Seemed like more than a lifetime. But he could hear the screen with Mondale's words as if they were right in front of him now. The Senator from Minnesota had been talking about the NASA proposal to go to Mars in the 1980s. "*I believe it would be unconscionable*," Mondale had said in that deadening twang of his, "*to embark on a project of such staggering cost when many of our citizens are malnourished, when our rivers and lakes are polluted and when our cities and rural areas are dying.*" Right—but the only thing that *had* died had been human exploration of space, its home beyond Earth. And Mondale, for all his talk, was just a senator then. Nixon as President had been the one.

All Jeff trusted himself to say to Sam was, "I think Nixon's going to surprise you about what he'll do—in Vietnam as well as in space."

"Oh, I have no illusions at all about Nixon and Vietnam," Sam said. "He says he has a plan to end the war—I'll believe it when I see it. We'll be lucky if we're out of there by the time the next Presidential election rolls around. But on space . . . look, tell you what. A friend of mine at Georgetown told me Nixon already has plans to set up a task-group as soon as he assumes office to map out the path for the space program post-Apollo. Surely that shows a commitment to space?"

"You're missing the point, Sam: *post*-Apollo. Why not continue it? Why not get some manned missions going to Mars?"

"So maybe he's just looking for a new name," Sam replied, "so he can distance the program from Kennedy, because missions to Mars deserve their own Greek god. Look, I'm going down to Washington for an association conference next month. Why don't you tag along? I could introduce you to my friend."

The conversation at the other table was heating up.

"The Greeks haven't done anything in two thousand years," one of the kids was saying. "Even politically, you people are the weakest country in Western Europe today."

"Papadopoulos can change that," someone with a Greek accent replied. "He's a great man—for Greece and the world."

The first student guffawed. "Papadopoulos is a jackass—another dictator with delusions of grandeur."

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Another voice with a Greek accent spoke up. "The Spiro Agnew—*he's* the greatest Greek in the world today!"

A strange feeling went through Jeff—one which he'd been trying to suppress, ignore, for the past few months. But it was getting harder to give it no for an answer.

The new Vice President was known in the future for his advocacy of the space program—his almost lone-voice advocacy in the Nixon Administration. Agnew would be Chair of Nixon's Space Task Group. The one that would propose NASA missions to Mars for the 1980s. The proposals that Mondale would ridicule and Nixon would kick aside in favor of the undernourished—unconscionably underfunded—Shuttle.

But what if Agnew were in a position not only to propose, but to start implementing NASA's schedule for Mars?

"I'd love to," Jeff said to Sam. "Let me just check with the board of directors at home to make sure we don't have any conflicting plans."

I'm just rapping with my friends, Ron. . . .

How many times had Jeff heard Nixon say that, or something similar, in the mirror imagisms he'd seen as a kid—"the mirrorim: more pixels per byte, the retina's delight"—Nixon in stark vivid detail in new productions and copies of holoscans and videos and movies made decades or more earlier? After JFK, Nixon had been the twentieth century president the twenty-first century had held in greatest fascination. And with good reason.

I'm just rapping with my friends, Ron. . . . Nixon to his Press Secretary Ron Ziegler, who had come upon the President talking to a small group of anti-war protestors at the Lincoln Memorial, in the early hours of the National Day of Protest in Washington, five days after the slaughter of four students at Kent State. Except the kids at the Lincoln Memorial were neither his friends, nor was Nixon "rapping." He was barely communicating with them at all—babbling, instead, about college football scores, oblivious to their anguish.

Nixon, with little or no Secret Service protection at the Lincoln Memorial before Ziegler had arrived—accounts differed, but all agreed he had impulsively left or snuck out of the White House, bent, perhaps, on explaining himself to whatever protestors he might encounter, or maybe just wanting to spend a few minutes with Lincoln, but certainly without the usual Secret Service compliment.

About as vulnerable as a president could be.

But that was still more than a year away. . . .

"Jeff Harris?"

Jeff turned, and extended his hand. "Good to see you again, George."

George G. Landry had bushy black eyebrows and a big moustache that looked out of place to Jeff, pasted on, but at the same time appropriate, even familiar. Then again, that's the way just about everyone had looked to Jeff since the day he'd arrived in 1963, more than 20 years earlier than his team had intended to send him, to stop the Challenger from exploding. Nothing about this world seemed in its proper place to Jeff, yet it all seemed so well known to him—like Jeff himself, when he looked in the mirror. An historian's dream come to life—except he was the history now.

"Quite a President," George said, and looked up at Lincoln. "Don't make them like that anymore, do they."

"With the rosy vision of hindsight they all look pretty good," Jeff said.

"Well, not all," George said. "I doubt our incumbent will come out of this presidency smelling like a rose. You would agree, am I right?"

"Who are you?" Jeff hadn't intended to be so blunt with Sam's friend, who had had some very interesting things to say to them about the Space Program at lunch today. Sam had a plane to catch

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back to New York right after the meeting. George had asked Jeff if they'd like to resume their discussion a bit at the Lincoln Memorial, since the April evening promised to be balmy. Jeff was delighted to agree. This was the third time Sam and he had been in Washington with George in the past few months, and Jeff was eager to find out more. All he knew about George and his moustache at this point was that they toiled in some murky, unnamed division of the President's "staff."

George breathed in deeply. "I can still smell the tear gas," he said, "from the October 1967 march on the Pentagon. Armies of the night. They were just kids, for crissakes. Exercising their constitutional right to assembly. Country's going to hell. Going to get worse."

Jeff thought about asking who he was again, but decided not to push it. Let him keep dropping these intimations of the future.

"I'm no one—at least as far as history is concerned," George said. "No rosy wisdom of hindsight to see me in. I'm off the screen—you gotta be seen in the first place to be seen in rosy hindsight, right?"

Jeff said nothing.

"You hate this war?" George asked.

"Yeah," Jeff replied. "The bitterness it's created in this country, the fusing of Vietnam and military and space in the public mind, poisoned the space program. I'm sure of it."

"And you're right. But you gotta hate the war itself. Do you?"

"Well, it's wrong," Jeff said. "It's unconstitutional—"

George grabbed Jeff's shoulder. "There are things in this life more important than laws and even constitutions," he said in a harsh urgent whisper. "You better think on that, my friend, before you do what you plan to do."

Jeff stared at him, started to speak—

George interrupted again. "The Vice President is much better than Nixon on space—you were right in what you said this afternoon. But is he any better on the war? You think Agnew will get us the hell out of there any faster than Nixon?" George's voice had risen to something more painful on the ears than a whisper.

"We were just talking hypothetically," Jeff equivocated.

"I'm not going to belabor the point," George said. "And I have a dinner engagement." He made a show of looking at his watch. "So, with regrets, I'm going to have to terminate this interview. But you need to think: Which is more important to you, Vietnam or space? And, if both are important, you'll need to think of a better way." George half smiled, nodded, then turned with a flourish and strode away.

Jeff was alone in the Lincoln Memorial. Thirteen more months to May 9, 1970, when Nixon would be here, almost alone.

Jeff breathed in the blossom air. Maybe he could smell some of the tear gas too. He wasn't sure.

"Space!" He shouted up to Lincoln, his fist clenched, his voice ringing. "We've got to get free of this planet!"

Laura was right—that was the only damned freedom that really counted in the long run. Why couldn't this world see that?

Jeff was on the computer again, hands massaging the console like he was driving a car, kneading Rena's back, making love to her face with his thumbs and his palms and his lips. He strained to see what was on the screen, but he couldn't quite make it out. Words . . . that didn't spell anything. . . . They never did, this far away.

Something soft snuggled up behind him. He could feel taut nipples pressing against his neck, breasts warm upon his back. He turned. Rena . . . No, Laura . . .

She kissed him softly on the eyelid. "Time to get up," she said. "It's way too early for man or beast, but you'll miss the bus if you don't get up now."

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"OK," Jeff said. He kissed Laura full on the lips, then leaned back and ran his hand through her hair. "I guess I was dreaming."

Laura put her head on his chest. "Comes with the territory."

"It's still in the future when I dream," Jeff said. "I've been cut off from it almost totally since I've been here, yet it's still in my dreams. Like a man who still feels his feet after his legs have been amputated."

"Lots of people maimed in the war—lots of people killed," Laura said. "I don't blame you for wanting to demonstrate in Washington. I'd just feel better if I came along—"

"No," Jeff said. "I want you here."

"So who's going to make sure you don't do something foolish? If you get yourself arrested, and the police start asking questions, looking into who you really are, where's that going to leave us?"

"That's exactly why I want you to stay back here," Jeff said. "I won't do anything foolish. I just want to ride down with the demonstrators in one of the busses—get a feeling for who they are. I can't just hang around here waiting another decade for the eighties to come along. But if something should happen to me, it's key that you be out of it, safe back here in New York. You're the only one, other than me, who has any inkling of what's going on."

Laura laughed, without joy. "We're worse than the blind leading the blind."

I'm just rapping with my friends, Ron. . . .

"True," Jeff said, and hoisted himself out of bed. All too true. But maybe something still could be done to change that. Up until these past months, he had been thinking of his role, and Laura's, solely in terms of how they could change specific events known to have happened—JFK's and the other assassinations, the Challenger explosion. Jeff was tired of just reacting, of trying to disinvent the tragedies that psychos, idiots, and god knows what else had made.

Today, he would try something more direct. He had no idea how many chances he would get to influence events back here, but directly doing something, rather than attempting to prevent something, seemed a surer way of getting what he wanted.

The bathrooms on the Jersey Turnpike and the inside of the bus all blended into one for Jeff. He looked at the blonde napping next to him, felt the gun in his pocket, and shivered. Easy enough to get a gun in Harlem, even in 1970, even for a white man. This was the world his ancestors were making for this girl. Drugs in the bloodstream, death on the street, people crowded with despair on a dirty planet with nowhere to go but down. The kids deserved more. The Earth deserved better. Could Jeff, with an act of violence that was anathema to all he had been until now—with a gun which was itself part of the illness he was trying to cure—make it all not happen? The girl opened her eyes for a moment and smiled at him. . . . He believed he could.

Are ya lis'nin' Nixon? Mercifully, there was no tear gas in Washington today. Just an echo of Pete Seeger's voice, questioning Nixon in song as it wafted across the lawns, a refrain from an earlier demonstration, emanating now from a kid with a banjo. History had been right about all those earlier protest marches—Nixon hadn't listened, the politicians never did. But what did it even mean to think that history was right, when the thinker was about to change it? Jeff was determined to make this demonstration of May 9, 1970, a little different. . . .

He walked for hours, taking in the shifting, gathering crowds, until the light began draining from the sky. Would that the soldiers could be so easily coaxed to leave Vietnam! Would that Nixon could be made to see that he was slamming the door on the sky, bleeding it dry, with every budget cut he inflicted on the space program.

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"Hey, you were sitting next to me on the bus, right?"

Jeff turned to see the blonde girl, who was holding a boy's hand, a good-looking guy with skin the color of coffee.

"Yes," Jeff said, and smiled at them.

"I think it's gonna go pretty good tomorrow," she said. "Reports on the radio say the crowds are huge already."

Jeff nodded.

"They're handing out cokes and pretzels over there." She pointed to a knot of people, far away.

"I'm OK," Jeff said. "You two go get something to eat. I'm gonna spend a little more time here."

"OK," she said. "You take care. Hey, I don't even know your name. You said you were a professor, right? Who knows, maybe I'll take a class with you someday."

"Arthur Bremer," Jeff replied. The name just popped out of his mouth. He hadn't given it any thought—but he didn't feel good about saying Jeff Harris. Bremer seemed an appropriate name to use under these circumstances. He, or someone else using his name, would take a shot at George Corley Wallace in just a few years, after having allegedly stalked Nixon. . . .

Jeff walked faster, then slower, back and forth, edging closer to the Lincoln Memorial. Nixon was still many hours away—if the historical re-enactments were right, he wouldn't show until 4 A.M.—but Jeff wanted to be in position. He cursed his inability, as he had so many times, to consult any records of his history—*his* history, the future from the perspective of here, the one he used to have at his fingertips when he lived and worked in the second half of the 21st century. He had to assume that Nixon could appear any time now. It was already dark. He'd watch for the black limousine pulling up to the steps of the Memorial.

Jeff thought again about his life, his former life, as an historian in a world that didn't exist yet—a world he had come back to change. He'd had no idea when he'd stepped into the Thorne in 2084 that he'd ever wind up at this time and this place. Just as he had no idea he'd be sucked back into 1963. . . .

To be knocked unconscious at the airport in Dallas when he was minutes away from perhaps saving JFK. Who—what—the hell had done that to him? Didn't matter, Laura said. Whoever, whatever, just rotten luck. It was an act of the Universe—a Universe with a stubborn streak, determined in some profound way to keep its timeline unmolested by time travellers.

But who could tell the difference between what was, and what was supposed to be?

Jeff looked around him. The memorial steps were almost empty. Good. Fewer witnesses . . .

Whatever happened, he had to do better here than he had with Kennedy.

He thought back to the Kennedy-Nixon debates of 1960, also immortalized in any screen that could show anything audio-visual. Kennedy looking so cool, Nixon sweating, shifty-eyed like Mephistopheles. Neither man could have had an inkling then of the transcendent roles history had consigned for them—or the role, in Nixon's case, that Jeff had planned for him and history now.

Jeff kept walking, around and around. Eventually he pulled out a sandwich he had acquired some time in the afternoon, a long time ago, and wolfed it down. His eyes scanned the people, the trees. For the first time since he'd been here, the trees were in the clear majority. He saw a woman walking alone. She looked like Rena. Why did so many women look like Rena to him? He had loved her and left her in 2084. And she had come looking for him in the past. And had died in 1964.

The sky was much darker now. He looked at his watch—it was 3:25 in the morning. Nixon would be here very soon. He felt his gun. It turned his stomach.

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A car pulled up. A man got out. Then another.

God, it looked like Richard Nixon. . . .

Jeff squinted—why hadn't he thought to bring binoculars?

Who was the other man? Manolo, Nixon's valet. Had to be. No Secret Service anywhere.

The two men were slowly walking up the steps.

Jeff touched his gun. He could run over to them right now. He could fire. And do what? Shoot Nixon in the back?

He felt his hand sweating on the weapon. He wondered if the wetness could ruin the firing mechanism. His breaths cut like little knives—

"Jeff . . ."

He jumped, nearly pulled out his gun and fired.

"Please." Laura put her hands on his arm. "You can't do this." Her voice was desperate.

"I have to," Jeff said.

"No," Laura pleaded. "You're not a murderer. You're better than that. Don't let . . . whatever it is we're in, don't let it do that to you."

"You're wrong," Jeff insisted. "I'm the one who's doing this thing—nothing's doing anything to me!" He kept his eyes on Nixon and Manolo. They were up the steps now, inside the Memorial, under Lincoln's shadow. He tried to move a little closer—

Laura was blocking his way. "You can't just kill someone—even Nixon!"

"No? Would you stop me if I had a chance to kill Hitler as a child?"

"I don't know," Laura said in quavering voice. "But Nixon's no Hitler—"

"Four students were shot dead at Kent State because of him!" Jeff said in a low growl. "He calls them 'bums'. They're just kids—they take my classes, I rode down on the bus with them. That's good enough reason for me." And Jeff was close to tears too.

"You don't know that Agnew will be any better," Laura said.

"You sound like . . . ah, that's who told you about this. That's who told you I'd be here. What'd he do? Phone you? George G. Landry?"

"Doesn't matter," Laura said. "What matters is I'm not going to let you kill anybody."

Jeff shook his head and looked at the Monument. A bunch of kids were in there with Nixon already. . . .

I'm just rapping with my friends, Ron. . . .

"So who says I'm going to kill the son of a bitch?" Jeff rasped. "Maybe I'll just disable him so he'll have to resign. Agnew supports the Mars proposal—hell, he's Chair of the Task Force that presented it."

"You don't shoot well enough to know how to wound him," Laura said. "You're liable to kill somebody else. You don't know shit about guns."

"She's right, Jeff," another female voice said from behind him. "Didn't you pay any attention at all in the training we received? Guns are strictly a no-no."

"Rena . . ."

A thousand questions screamed in Jeff's skull. Rena was killed in 1964—he'd held the damn *Daily News* with her face and the article right in his hands—how could she be here now? Was the newspaper wrong? Had Rena somehow come here first? But why? And how? Laura and he had figured out the irresistible magnet that 1963 was to time travellers . . . or thought they'd figured it out. . . .

The only thing Jeff was sure about was that this wasn't a dream, he was so glad to see Rena . . . that, and his time somehow had passed to shoot Nixon. It was a subtle thing, but Jeff knew it was over.

He looked at Lincoln. The entourage was still there, but Jeff felt sapped, almost drugged, his circuits too overloaded with questions about Rena, with joy at seeing her again, to even pull out his gun, let alone shoot anyone.

He was a very different person, a

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detached part of him realized, than he had been just a few seconds ago.

Which one was the more real?

Rena tugged on his arm. "Forget him, Jeff. That's not you. You were meant for other things."

Laura took his other arm.

"I've got the car nearby." Jeff thought he heard Rena say. "The pickup on these 20th-century models is amazing."

The car seat felt comfortable indeed after this long day. Jeff's head felt muzzy. Rena drove, Laura gave him some tea.

He had so many questions. Had Rena come here in a Thorne? That opened up all sorts of possibilities. His Thorne had disappeared in that vandalized student lounge. Laura's had vanished a few days after her arrival, sucked back at the behest of who knew what force or command into its Artificial Worm Hole. . .

Like the nothingness his brain felt it was being sucked into right now. . . His eyelids put up a desperate rear-guard action to stay in touch with what was happening. But they were hot pasty lead. . . .

The last thing he heard before he gave in to sleep was Eddie and the Cruisers singing "Season in Hell" on the radio. . . .

Jeff woke up the next morning, his mind clearer than it had been in years.

Laura was in the kitchen making breakfast in their New York apartment.

"You drugged me last night," Jeff said.

Laura looked at him, nodded.

"Twice," Jeff said. "Once when you first grabbed my arm near the Lincoln Memorial." Jeff touched his arm with his fingertip. "I can still feel a little puncture mark here—what was it, some sort of contact needle? And then in the tea you gave me in the car. Tea's supposed to keep you awake, not put you to sleep."

Laura said nothing.

"How the hell am I supposed to trust you at all now?" Jeff barked.

Laura stared very hard at him. "You can trust me to drug you and do anything else to stop you from murdering someone—even Nixon. You can count on my not letting you become the very people you despise. You risked your life and even the Challenger plans once to stop Lee Harvey Oswald. You've been miserable about not trying to stop Sirhan. Yesterday you were this close, *this* close, to becoming one of those monsters yourself!"

Jeff looked away. "Where's Rena?" He wheeled around, saw the bathroom was open and no one was in it. He could see the foyer and living room were empty too.

Laura took a shaky breath. "She's gone."

"What? You let her go—"

"It was what she wanted, insisted on doing," Laura said. "The Thorne only has room for one. Who else could have been the one to get in that? Your going back would cause much more of a disruption at this point—remember in my reality, my future, in which the Challenger doesn't crash into the schoolhouse, you never returned to 2084. And as for me . . . I just couldn't . . . I mean, I didn't want to go and just leave you here."

Go and leave me nice and cuddly with Rena you mean, *that's* what you didn't want, a voice in Jeff said. But he said nothing aloud. Laura's reasoning was not wrong. "Why did she have to leave so soon? We could at least have talked this over."

"She wanted to get to 2084 as soon as possible," Laura said. "She was back here looking for you—one of the ads you placed in the papers a few years ago made it through to the future after all. So she knew your address. When she showed up yesterday, I knew who she was. I told her about your being in Washington, and she realized immediately what you might be up to. I guess I knew it too, but didn't want to admit it. But as soon as Rena said it, we got on a plane, and I caught a cab to the Lincoln Memorial, and she got the car—"

"OK, OK, I know that already," Jeff said. "Why'd you let her leave today?" He slammed his fist on the table.

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"That's what she wanted. I couldn't stop her," Laura said. "She thinks she's going to 2084, and then to 1986, to stop the Challenger." Laura put down what she was doing. "For all we know, maybe she is. What was I to tell her—don't go, don't ever get into a damn Thorne again, because, if you do, it'll bring you back to 1964, where you'll be run down by a goddamn bus? Is that what I should have told her? Would she have listened?" Laura was sobbing.

Jeff found himself consoling her. "I guess we can't know that for sure."

"We don't know a damn thing for sure," Laura said. "Maybe we were wrong about the 1963 magnet. . . ."

"I don't think so," Jeff said. He closed his eyes, tried to picture himself standing near the Lincoln Memorial yesterday, Laura and Rena rushing to him from two different directions, bent on stopping him from doing what he was surely about to do.

"You two were like antibodies plunging towards me yesterday, set upon me by the Universe's immune system to protect the status quo. You were pulled out of New York, Rena out of the time flux. That's part of what's going on at the end of 1963 too—why the terminus there for time travel is so deep, so well worn. So many people going back to try to prevent the assassination of JFK. But even more, I'd bet, a lot more, pulled into there to make sure the assassination takes place."

"That's horrible," Laura said. "Why must the status quo be Kennedy's death?"

Jeff shook his head. "I don't know."

"What's the status quo that the Universe is trying to protect for the Challenger?" Laura asked.

"That's a good question," Jeff said. "It's like there's a deeper reality, a core realm of events, that nothing can change, that all forces stand ready to protect. All we seem able to do is push around the film on the surface of the pond."

"Rena had a plan," Laura said.

Right, but one of the twisted advantages of time travel, Jeff had found out the hard way, is that you find out right away when your plan has failed. You see its ruins staring you in the face, in the same damn world unfolding just as you did not want it to.

Rena's plan was logical enough: her Thorne had landed her in 1970, so she reasoned that whatever the power of the 1963 basin of attraction that had sucked Jeff back in his Thorne and its AWH to the eve of the JFK assassination, it could not be all powerful. True enough, apparently. So Rena thought she could take her Thorne back to 2084, and tell the team what had happened. Get them to build two fleets of Thornes. Even if that took five years, a decade, that wouldn't matter to Jeff and Laura, because from their vantage point, when one of the two fleets arrived, no time would have passed. And that fleet, by virtue of its sheer numbers, should create enough attraction in 1970 to offset at least somewhat the immense power of the 1963 basin. Jeff and Laura could then each take a Thorne back to 2084, where they could live happily ever after (Jeff could hear the slight sarcasm in Rena's voice as he imagined her saying this to Laura). Meanwhile, the other fleet of Thornes would aim for 1986—where, again, by virtue of its numbers, it would presumably offset the pull of 1963—and it would do in 1986 whatever was necessary to stop the Challenger explosion.

But obviously something in that reasoning was wrong. Rena hadn't been aware of Jeff's "antibody" theory for why her Thorne had come back to 1970—she'd drawn mistaken conclusions about the strength of the 1963 basin. It was not omnipotent, true—but it took some sort of extreme crisis, like the endangering of an historically very significant President like Nixon, to counteract its weight, to attract whatever

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was necessary for the job, including a time traveller like Rena pulled out of a fall to 1963 for a stopover in 1970. And when the job was accomplished—Jeff's rendezvous with Nixon aborted—the stopover was no longer necessary. So when she stepped back into the Thorne she went not where she wanted—to 2084— but to where she was originally being drawn—to 1963.

To her death.

"You see, I knew that Rena wasn't coming back, that no fleet of Thornes would ever appear, the minute you told me about her plan," Jeff said to Laura, time and again. Because Rena and the Thornes would have been there already that very morning had they ever been going to appear. The days, months, years that followed were just a redundant chorus of confirmation.

And the space program continued in its invisible decay, its fixation on the deathtrap shuttle, the road to the Challenger paved with good and not so good intentions. . . .

"Our problem," Laura said one morning in the early Spring of 1972, "is that we have no way of telling, at this point, just when the fork occurs in our two different realities—yours in which the Challenger not only explodes but takes out a whole schoolhouse of children in Miami, mine in which it explodes just after takeoff and kills only the astronauts. Presumably the space program survives in my reality because no other people were killed in my Challenger explosion—the closest it came was a solid rocket booster, still carrying propellant, headed straight towards New Smyrna Beach after the blow-up. But the Air Force detonated the booster's destruct package by radio signal at 100,000 feet."

"Right," Jeff said.

"But you and I are both here in 1972, and this reality seems the same so far for both of us," Laura said. "It's exactly, at this point, as each of us grew up in the 21st century knowing it. So the question is, how do we know if this is my reality or yours? The answer to that affects what, if anything, we do to make sure this stays my reality, or leads to it."

"I still think the third choice of changing the political structure altogether so that Mars, not the shuttle, spearheads the space program is the best bet for the future," Jeff said. "But that's obvious—if apparently not possible."

"Not so obvious," Laura said. "If we try for that future, we risk losing my future, in which the shuttle is still center stage, but with just the limited explosion and consequences—and the beginning of some serious Mars exploration at last in the twenty-first century."

"I guess," Jeff admitted, grudgingly. "Not to mention that we already missed our best opportunity for getting the Mars program in motion—Nixon's still in office. 'I have decided today that the United States should proceed at once with the development of an entirely new type of space transportation system. . . .'" Jeff did his impersonation of Nixon's announcement to reporters at San Clemente on January 5, adding in the shifty eyes, shaking jowls, and Nixon's patented hands-raised-above-his-head-in-victory gesture for good measure. "He had the gall to say he was especially pleased about the shuttle because it would make space work 'safe and routine'! Do you believe that?"

Laura poured Jeff some tea.

"If we're stuck with the shuttle," Jeff said, "then we need to get word to NASA about the O-ring problem. But even that's a lot more complicated than it seems. The O-rings were the culprit, as far as we know, in both your and my history. But who knows, maybe there was something more at fault in yours or mine. And there's the question of just when should we contact NASA. The plans I brought with me from the future are almost useless until 1984. If I approach someone at NASA now, and say, hey, don't give Thiokol the booster contract, you're on your way to building a Russian-roulette killing machine that will

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break the heart of America, I'll likely be laughed off as a crank."

"There were plenty of flaws in addition to the O-rings," Laura said. "The very first shuttle flight—Columbia's—lost some of its heat tiles. One of the fuel cells failed in the second flight. The astronauts' spacesuits were defective in the fifth flight—even though the contractors gave them their seal of approval. Fortunately, the crew abandoned their spacewalk because of upset stomachs—had they used the suits, they would have exploded. The engineers were dead-tired for a later flight and missed a sensor from a fuel hose that had broken off and was lodged against a valve. That little oversight, discovered by accident, could have caused the engine to blow up. The list goes on and on."

Jeff shook his head. "The wisdom of hindsight again—except we goddamn have it and still haven't a clue what to do."

"Well, maybe we should start with something a bit easier—like whom at NASA or wherever should we contact," Laura said.

"Is that really easier?" Jeff asked.

"I don't know," Laura said.

Jeff sighed. "The only one I can think of seems to have disappeared. I'll ask Sam about him again. I still think George Landry may somehow be a key to this."

No need to be afraid. . . . One of the things Jeff had really loved about spending the 1960s at City College in New York was the scraggily group of kids singing Beatles songs in the Alcove behind the North Campus cafeteria. All that La Jolla seemed to have was this one guy, leaning up against the pastel grey building that housed the Western Coordinating Sciences Institute on Silverado, singing his song. But his falsetto gave Jeff the chills.

Jeff carefully slid a five-dollar bill under the guitar case. No sense letting it blow away in the warm ocean breeze.

"Thanks, mate," the singer said.

The security guard inside looked at Jeff, then at the picture of Jeff he somehow already had on his desk, and motioned Jeff to the flight of stairs in the far left corner. The building only had two stories, and there was nothing but the pantomime guard on the ground floor, so Jeff assumed that the second floor would have what he was looking for.

It did, and more.

"Been a while, hasn't it," George G. Landry said and extended a calloused hand.

Jeff took it, and tried not to wince from the vise-like grip. "I appreciate your seeing me," Jeff replied. He didn't say "on such short notice," because it had in fact taken two months of intense hounding of Sam to make this happen.

Landry pointed to a chair. "Make yourself comfortable," he said to Jeff. "And let's get down to business. You'd like my thinking about the space program."

Jeff nodded. The chair was indeed comfortable, but nothing else about this meeting was. The office itself looked wrong—like Landry had just put it together for this meeting. But Jeff reminded himself that although he was an historian he was certainly no expert on 20th-century office decor—certainly not what passed for it in late 20th-century California.

"I'm going to be blunt," Landry said. "You wanted this meeting—here I am—I'm going to tell it to you like it is—as some of my current colleagues like to say. You're an amateur. You don't know what you're doing. You'd be better off keeping the hell out of this."

Jeff knew better than to ask Landry who he was. He remembered Landry's non-answer at their last encounter. Nor did he ask just what this Western Coordinating Sciences Institute "coordinated"—he had a feeling he would find out soon enough. "Go on," Jeff said.

"I told you last time that you were barking up the wrong tree trying to remove Nixon on the hope that Agnew

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would be better for the space program. The problems with space run deeper than that. And Nixon and Agnew are both the source of other threads that need fixing."

"Some of them would have been fixed with Nixon gone," Jeff said.

"True," Landry said, "but you went about it the wrong way. You can't make history go your way by blowing away presidents—hell, you can't make history go your way by attempting to *stop* presidents from being blown away either. You of all people should know that."

Jeff reddened. "Who the hell are you?" Now he couldn't stop himself from asking.

Landry sneered. "I'm someone who knows how to get things done in this business. We do it quietly, in little ways, when no one is watching. You know, the nail that fell off the shoe of the horse and the damn nag broke its leg and the army lost the battle and the war and the empire collapsed and all that. Except we remove the nail, or slip in a defective one—a little break-in in a hotel room, a little tip-off to a lucky security guard, that's the way you get rid of a president. Get my drift? No bullets, no bullshit, no bloodshed."

"I'm a fan of none of that," Jeff said. "But Nixon's gearing up to beat McGovern in a landslide, and still hasn't ruled out nuclear weapons in Cambodia or North Vietnam." Upset as Jeff was, he still realized that he was better off not revealing certain explicit brutal facts about the near future. Nixon's nuking of Cambodia in 1976 was the only use of nuclear weapons other than Hiroshima and Nagasaki. That secret devastating mission, no secret to Peking, had come razor-close to starting a full-fledged nuclear war—only the death of Mao that same year had sown enough confusion in China to forestall it till the crisis had passed. "Even without the space program, there are a dozen reasons Nixon should be out of office," Jeff confined himself to saying.

"And what I'm telling you is that that's going to be taken care of," Landry said. "Nothing we can do about the landslide, but we're on top of the nukes in Cambodia. That won't happen—I can assure you. Nixon will be preoccupied with other things. And he'll be long gone—via *legal* means—by the time the next election comes around. You'll just have to take my word for it. Watch the news next month."

"'We'?" Jeff asked.

"Never mind who we are. You and your girlfriend just stay out of our way, let us do our work. You understand?"

"What about the space program?" Jeff insisted.

"You're going about that the wrong way, too," Landry replied, tiredly. "No one's going to pay any real attention to your concerns about the shuttle's safety. You'll get through to a few intelligent engineers, they'll look into it and see what you're saying is right, but their reports will be ignored. They'll be filed away somewhere. That's the way *that* can of worms works. Too much political pressure on NASA."

"So what are you saying?" Jeff asked. "It's all hopeless? No real chance for space after all?"

George G. Landry gave Jeff a long, cool stare that seemed to cut not only through Jeff's eyes, his brain, his soul, but through the past nine years that Jeff had been here, years of fog in fast retreat now from the sun.

Finally, Landry spoke. "Are you willing to do what's necessary?"

Jeff stepped out on the balcony of the Century Village apartment he had managed to sublet in West Palm Beach. The weather was gorgeous this Sunday—sunny and warm and just what one would expect of a late January morning in Florida. Jeff squinted at the sky, in the direction in which the Challenger would be taking off. Today would be a perfect day for the launch. Unfortunately, it wouldn't happen until Tuesday, when

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the weather would be cold enough to prevent the crucial expansion of the O-rings.

Jeff wished there was a way he could heat up the sky. Converge the requisite lasers over a suitable area—shunt the sun's energy from warmer climes. But those techniques were nearly a century away from being invented. Much like Jeff himself.

But here he was. Gone from 1972 to 1986, with barely a call goodbye to Laura, via a time travel device that made the Thorne look like a Model T. Except "don't let the glitz fool ya," Landry had advised, "the chassis may be sleeker, but the vehicle obeys the same underlying laws, the same physics of time travel, as your Thorne." Meaning it was just as subject to powerful basins of attraction. Rena's Thorne, attempting to move forward to 2084 from 1970, had been sucked back to 1963—as had Jeff's and Laura's Thornes, travelling back from 2084 and 2094, in the first place. "The pull of the 1963 basin is almost irresistible to vehicles travelling back from anything approaching a century or more in the future," Landry had told him. So Laura and he had essentially been right in what they'd concluded in what seemed so long ago now, in 1964—when they had first realized that perhaps their presence in the past could make a difference, and mitigate the worst of the Challenger disaster.

But the fall of 1972 was apparently just far enough away from November, 1963 that a time-travel device attempting to move forward could break free—as Rena's in 1970 apparently had not. That was Landry's theory, anyway. For Jeff, to have been drawn back to 1963 again would have been a nightmare so agonizing that he was by no means sure his sanity could have survived it. But he'd held his nose, clutched his hopes, and put Landry's machine and the theory that came with it to the test. He'd been willing to do what was necessary to get this far. And here he was.

But as Jeff looked at the sky—blue as a newborn's eyes—that would soon see, hold, so much fire, so much pain, he couldn't say with certainty that he had what was necessary to finish the job.

"Small things," Landry had stressed, over and over, "that's the only way to get around the universe's damned resistance to time tampering. You can't do it by assassination, by preventing assassination, by causing a shuttle to blow up on television, by preventing it from blowing up. That's all beyond our reach. The most you can do is redirect the explosion—cause it to happen a little sooner, over a different area, with a different result. . . ."

Yeah, that jibed with Jeff's experience with his great-great-grandmother in 1964. A small thing—still wonderful, and hurtful, to think about. He had asked her to convey word of their brief meeting to her grandson, Jeff's grandfather, in the hope that he would in turn pass that word on to Jeff. And his great-great grandmother did, and his grandfather had, giving Jeff a tiny but irrefutable proof positive in his mind that he could indeed do something in this past that could alter the future.

Small things. Landry's people had learned that two things had caused the Challenger to explode and crash into that Miami schoolhouse filled with kids in Jeff's reality—the reality that was still on cue to happen now in less than 24 hours, unless Jeff did something to prevent it.

At T plus 0.678 seconds—0.678 of a second after takeoff—photographic evidence showed a puff of first off-white, then grey smoke spurting near the aft field joint of the shuttle's right rocket booster. This was the first indication that the O-rings had not slipped into place. The result would be the catastrophic explosion just after T plus 73 seconds of flight. There was nothing small about that. There was no way to stop it once the O-rings failed. And there was no way

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to stop the O-rings from failing. Landry had been all too right about that—every warning had gone unheeded.

But a second malfunction had caused the Challenger to veer way off course, to Miami, before the explosion. Wind shears encountered at T plus 36.990 seconds—greater than any experienced on previous shuttle flights—had defeated the adjustments of the computerized navigational equipment onboard. "The most dangerous weather phenomena affecting aviation," Ralph Nader once had written. The result would send the Challenger on its deadly course to Miami.

Landry was betting that that errant path, the result of powerful winds and impotent automated guidance, was something that human intervention at just the right moment might avoid.

A small course correction, made by a human pilot at just the right time, forewarned and forearmed. Was it small enough to escape the Universe's unblinking attention?

Small things worked. Whispers to great-great-grandmothers. Not murders.

What Jeff still wasn't sure about was suicide. . . .

"Jeff Harris, Western Coordinating Sciences Institute, good to meet you." Jeff extended his hand to an attractive brunette, whose press pass fixed just above her bosom said *Cleveland Plain Dealer*. She had taken the last remaining seat next to him, at the end of a long cafeteria table.

"Mary O'Brien," she said and smiled. "Western Coordinating . . . I don't think I've heard of them. A new news service?"

"Sort of," Jeff replied. He sipped his tea and silently cursed the taste of styrofoam for the thousandth or more time since he'd left his century. "It's a new online service—a private operation for chief executives and other important people who have personal computers and modems."

"Online? Ah, you mean like The Source? I was talking to someone here last month who said he sends all his stories in that way—his editor has an account on the system."

"Exactly," Jeff said.

Mary nodded. "His paper got so disgusted with all the Columbia's delays that they brought him home, ruined his Florida fun. God, there were so many problems with that one that people began calling it 'Mission Impossible'. NASA was none too pleased."

"They're under a lot of pressure," Jeff said. "Hard to operate on the strangulation budget Nixon left 'em."

"Yeah," Mary said. "At least Reagan seems more gung-ho. Well, let's hope they get this one off the ground soon—those poor astronauts must have pains in all kinds of places lying out there on their butts for four hours."

Jeff didn't reply. He knew it wasn't going to happen today.

The announcement came over the loudspeakers a few minutes later, at 12:35 P.M. Today's launch was cancelled—crosswinds above the runway were clocked at more than 10 feet per second above the highest allowable speed.

"Jeez," Mary said, and got up with dozens of other reporters from nearby tables. "Well, they're right to be careful about those wind shears, though. Brought down that Delta in Dallas last August, remember? Killed 135. And the Pan Am in New Orleans in 1982? Winds slammed into it, tossed it around like a toy. Only 9 survived that one—153 died. I covered both those stories. Jeez, one of the nice things about doing the Shuttle is we don't have to worry about those kinds of things, right?"

Jeff looked away.

"Well, good talking with you," Mary said. "Let's hope for better luck tomorrow. Maybe we'll run into each other again." She smiled.

"Sure," Jeff said, and smiled back. But he knew that wasn't going to happen either.

* * *

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"Mission Impossible" . . . the press's sarcastic name for the seven-times delayed Columbia 61-C flight, the last shuttle mission before the Challenger, which indeed had finally flown a successful mission in January, though its delays had pushed back the Challenger's original launch date of December 23, 1985. Jeff wondered if the combination of that and the original TV series, or the later movies and mirrorims, had given Landry and his colleagues the idea for the plan that now was Jeff's to implement.

The plumbers and what they had done to Nixon with Watergate were after all classic *Mission Impossible*. Jeff had read up on all the pertinent new history in the several weeks that he'd been here. Impressive. He had to give Landry credit. And Landry had assured Jeff that his people would take care of all the relevant details for the Challenger.

Except, of course, the most important one.

Jeff looked in the mirror.

The use of masks to make the MI operatives look like other people had been a fundamental mechanism in all of the show's incarnations. Of course, in the early TV shows and even the first series of movies, the mask technology was more science fiction than reality. But by Jeff's time, skin weaves from DNA banks with huge varieties of features were commonplace. And Landry's technology was even better. Construction of an utterly lifelike face-mask that looked like someone else was no problem.

Landry's team had indeed covered the other details. Jeff had studied the conversation logs of the Challenger's astronauts on this fateful day, and had memorized all of his lines. The medical records would show that the voice of the astronaut he was impersonating had had a slight cough and a sore throat on this day, and that would account for any perceived difference in voice quality. Tiny puterwafers inserted in appropriate places in Jeff's skin would generate false readings consistent with the general medical data of this astronaut. Jeff was already the same height, and the age was right. They were both about 40.

There was no way of stopping this mission. Jeff had no choice but to believe that now.

He had failed to prevent the assassination of JFK, he had failed to kill Nixon, and he had been unable to stop this mission—the specific circumstances were different in each case, but all had hit the same unfathomable brick wall. He had spent months and months after that first meeting with Landry in La Jolla, trying in vain to get NASA, Thiokol, anyone to listen about his warnings about the O-rings. Most of his calls, his memos, his letters, never seemed to get through. And when they did, they seemed to have no effect at all. The Shuttle continued on its inexorable trajectory to tragedy.

In a few hours, Thiokol's engineers would recommend that the launch not proceed due to the very O-ring problem in the cold that would cause it to explode. Made no difference—the managers outvoted the engineers anyway. Jeff was certain that had he been there with a videotape of the explosion, those plumes in the sky, that burning schoolhouse in Miami, it would have made no difference either. Somehow the launch would have proceeded anyway.

Small things. That was all he had left. Like being inside the Challenger, after its launch, to make a little, manual course correction so that, when those vicious winds began blowing with the O-rings gone, the Challenger would go nowhere near those kids in Miami.

Jeff had been trained intensively for ten weeks. The simulation had been exactly like the inside of the Challenger, with the wind shears projected in all their force and fury. Far too strong, and sudden, for the nav computers to handle—even if they were performing at peak efficiency, which Jeff knew was no sure thing, given the spotty record of so many other systems on the shuttles. NASA had been

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right to postpone the launch yesterday. And today's wind slam would be even more overwhelming—and unexpected. Microburst out of nowhere, down draft from the base of the cloud, wind smacks the ground and comes back up like an inverted mushroom and the Challenger's hit fore and aft by headwinds and tailwinds, spun around indeed like a toy to Miami, a toy with tons of explosives. But Jeff with the wisdom of hindsight—this time all too terribly clear—would know just what to do.

Landry's people would help Jeff take the pilot's place. Jeff was glad at least that one of those astronauts, heroes to the rest of the twentieth and the twenty-first century, would survive this.

But not Jeff.

He looked again in the mirror, tears in his eyes, and saw the face of Michael J. Smith.

Jeff waited in the bathroom. Souped-up security passes courtesy of WCSI and a mask of his own face worn over Smith's had gotten him this far.

Mike Smith, Jeff knew, was finishing his breakfast. Soon the Challenger pilot, anticipating his first trip in space, would make a quick last pitstop in the bathroom. Jeff carefully peeled off his own face so that he once again looked like Smith. As soon as the shuttle pilot entered, Jeff looking like Smith would hustle out of the bathroom and join the others in this mission. Landry's people would see to it that the real Smith was safely and quietly escorted out of the bathroom and off the premises.

Jeff heard a noise at the door and tensed.

Someone walked in. The height was right, but from what Jeff could see of the man's face, as he turned to the urinal, this was not Smith.

Jeff looked at his watch. Mike Smith should be here any minute. He hoped the man at the urinal concluded his business quickly.

The goddamn guy was humming now as he finished up. Jeez, the voice sounded familiar. Jeff tried to stay focused. He'd heard lots of voices around here as he'd checked out the place as best he could in the last few days. But something about the glimpse he'd caught of the guy's face, just a quick profile at most, ate into Jeff as well. He'd studied photos of hundreds of NASA people who worked here, and of course of all the astronauts, but this guy seemed like none of those—

He flushed, rinsed his hands in the adjacent sink, and dried them. Then he turned and looked straight at Jeff, who was standing in a half-open stall near the door.

Sweet God Almighty!

"Hello," the man said. "There's no easy way for us to be introduced, so let's just leave it at, 'Here I am.'"

Jeff was unable to speak.

"The first thing I need you to acknowledge is that my being here shows your plan to go up in the Challenger won't happen," the man said.

Jeff could see that was true. But he also knew that some aspects of the future were nonetheless subject to change. He might still be able to get on the shuttle, sacrifice himself as planned, and then the older version of himself that he was now confronting would never have been here. "This must be very painful for you," Jeff said. "I still carry the turmoil everyday of what it was like to change my—our—memory when I met our great-great-grandmother."

"Yes," Jeff's older self said. "It's painful, though I prepared myself as best as I could for the sudden rush of memories I knew I would have when I met you. It's like I'm living this twice, for the first time." He shuddered. "Let's get out of here now, shall we?"

"If I go with you," Jeff said, "if I don't take Mike Smith's place today, then the Challenger will kill all those children in Miami, and the future of the space program too. We'll have my future, not Laura's. But that's what I've been working

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for these past 10 years to change. Please. You already know that. Don't mess up the last chance we have."

The older Jeff shook his head. "There's no time for me to spell it out to you now. Just come with me." He took a few steps towards Jeff, and pulled out some sort of weapon.

"Keep away!" Jeff moved a pace towards the front door. He managed a derisive smile. "I *know* you're not going to kill me with that. And if you stun me—how are you going to explain lugging Mike Smith's body around?" But Jeff knew he was on shaky around. He had to stay conscious if there was to be any chance of his making the switch with Mike Smith. He couldn't even afford a tear in his outfit which might attract attention. He looked out the door. Smith should be here any second. He looked back at his older self, who was still approaching.

Jeff had to do something quickly. He smiled weakly at his older self, as if acquiescing, then turned on him with a ferocity he never knew he had. He smashed his older's self's arm against the wall, then battered it with his fist until the weapon fell. He punched him repeatedly in the solar plexus. His older self sagged blue-faced and breathless to the floor.

Jeff walked out and closed the door behind him. For a moment he hoped he hadn't hurt his older self too badly, then realized how absurd that concern was: what he was about to do would eliminate his older self from existence entirely.

But how would he make the switch now? He couldn't continue waiting in the bathroom. But neither could he just burst in on the Challenger crew at breakfast with Smith still there. Where was the pilot, anyway? Why wasn't he here?

It didn't matter.

"Please come with us, sir."

Three men suddenly were in back of him, around him, escorting him away. One had a gun to his side.

"Where are you taking me? Look—"

Jeff received a slight but firm shove in response.

"If you're with Landry, you've got the wrong person," Jeff spoke quickly. "You're here too early—I know I *look* like Mike Smith, but he isn't here yet. I'm Jeff Harris."

No reply.

Jeff savagely elbowed one of his escorts, broke free of another.

The third pointed a small, snub-nosed pistol in his face.

"Listen to me," Jeff said as slowly and deliberately now as he could, "you're making a very big mistake." He looked the man in the eye. The expression he saw was even less compromising than the barrel of the gun.

Then he felt a twinge of something in the back of his neck, and all he saw was a swirling, darkening blur of red, brown, black.

"Jeff . . ."

He opened his eyes to a series of faces, like a carousel of corneas being fitted to his eyes, except each showed a different frame, a different face. . .

Rena . . . Laura . . . Landry . . . Jeff at 10 . . . Jeff at 50 . . . Jeff at 40 . . . Michael Smith . . . Rena . . . Christa McAuliffe . . . JFK . . . Bobby . . . Dion . . . Laura . . .

"Jeff . . ."

The spinning got slower . . .

Rena . . . Laura . . . Landry . . . Nixon . . . John Lennon . . .

I'm just rapping with my friends, Ron. . . .

No need to be afraid . . .

And slower still . . .

Rena . . . Laura . . . Jeff at 40 . . . Rena . . . Laura . . . Laura . . . Laura . . .

"Laura," Jeff said. But she looked different, older. "What's—"

"Shh, baby." She put a finger, cool, to his lips. Jeff felt tears on his cheek. He realized they were hers.

"I missed you so much," she said.

"I'm sorry," Jeff said. "I know."

"I tried to track down Landry," she

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said. "No way I could do it in the seventies—he and that Western Coordinating Institute left no trail. So I had to take the long way home to you—live these thirteen years day by day. But I never gave up hope I would find you."

"I'm sorry, angel, so sorry," Jeff said again, and he hugged her. "What time is it?" He pulled away.

"It's 11:30," Laura said. "The Challenger lifts off in a few minutes. We'll be able to see it from here."

Jeff looked around, saw he was in the front seat of a car, passenger's side, parked along some field with shrubs. "We've got to stop them!" He moved to get out of the car. His body ached all over.

"It's too late for that," Laura said, tears in her voice as well as her eyes.

"It's *not* too late," Jeff insisted, and opened the car door. He turned back to Laura. "All we've been struggling to accomplish—limit the damage of the Challenger, save those little kids! We can't let it happen!"

Laura appeared not to hear. "I tried so hard to stop the whole flight—call it off—get the O-rings fixed. I tried so hard, so many things. But it just wasn't possible—something always seemed to get in the way." She shook her head, looked back at Jeff, put her hand on his. "But I think I may have headed off the worst."

"How?" Jeff looked at his watch. It was past 11:30 indeed. No way that either of them could stop anything having to do with the Challenger now.

"I spoke to Mike Smith years ago," Laura replied. "He thought I was crazy—this mission hadn't even been scheduled then. He wasn't even an astronaut then. But you know, I guess if you're cut out to become an astronaut, you have a sense of what science can accomplish not only now but in the future. So I told him who I was, about the Thorne, how I got here, what would happen to the Challenger one day, everything. I think he still thought I was crazy—then. But he heard me out. And when the wind shear hits 37 seconds after lift-off, he'll see it on the instruments, and I think he'll remember what I told him. And he'll do what needs to be done. He'll make sure the Challenger flies far away from Miami." And she broke down into sobs and tears.

Jeff came over to her side of the car, pulled her out and into his arms. They both were crying.

"How'd you know where to find me?" Jeff asked. "I mean, Landry's people—"

"I finally managed to break through to part of Landry's operation just a few months ago. I saw some of the plans. I knew you'd be here. I knew Landry's men would be kidnapping someone—you, an astronaut, I couldn't get to that piece of the plan. But I figured I'd hire my own team, intercept Landry's, and see whom they'd taken. Maybe it would be you. And I got lucky." She touched his face. "That mask only fooled me for a moment."

Jeff touched his face too, realizing that the mask was off.

They turned in the direction of the Challenger. It was starting its liftoff.

And they looked at the sky, hands clasped, eyes singed from the smoke that would soon plume far from the Earth, far from the schoolhouse, close to the heavens. ■

The invention of writing formed the real beginning of civilization. As language distinguishes man from other animals, so writing distinguishes civilized man from the barbarian.

— William F. Friedman

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THE LIFE CYCLE OF AN IDEA

by David A. Roach

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1. The ignorant superstition of naked unwashed savages;

2. Outrageous blasphemy, and an affront to all which is right and holy;

3. Dangerously reckless speculation, but there may be a grain of fact in it somewhere;

4. Well, the obvious truth; so transparently self-evident, even a child could see it!

5. The commonly accepted explanation, true enough in most situations, but on very close inspection there are some serious loopholes;

6. Traditional and conventional lore, but to be honest about it, we just stick with it because nothing better has been formulated;

7. Obsolete thinking, pretty much discredited in enlightened circles, although a few die-hard supporters of the notion can still be found;

8. Hilarious hokum, but the imbecilic delusions of bygone days teach a broader lesson: it is unwise to accept anything, no matter how plausible, at face value;

9. The ignorant superstition of naked unwashed savages.

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Part Three of Four

Joan Slonczewksi

The Children Star

Establishing communication requires effort by both parties, but there are even more basic requirements—like being able to tell that there is another party and that he, she, or it is trying!

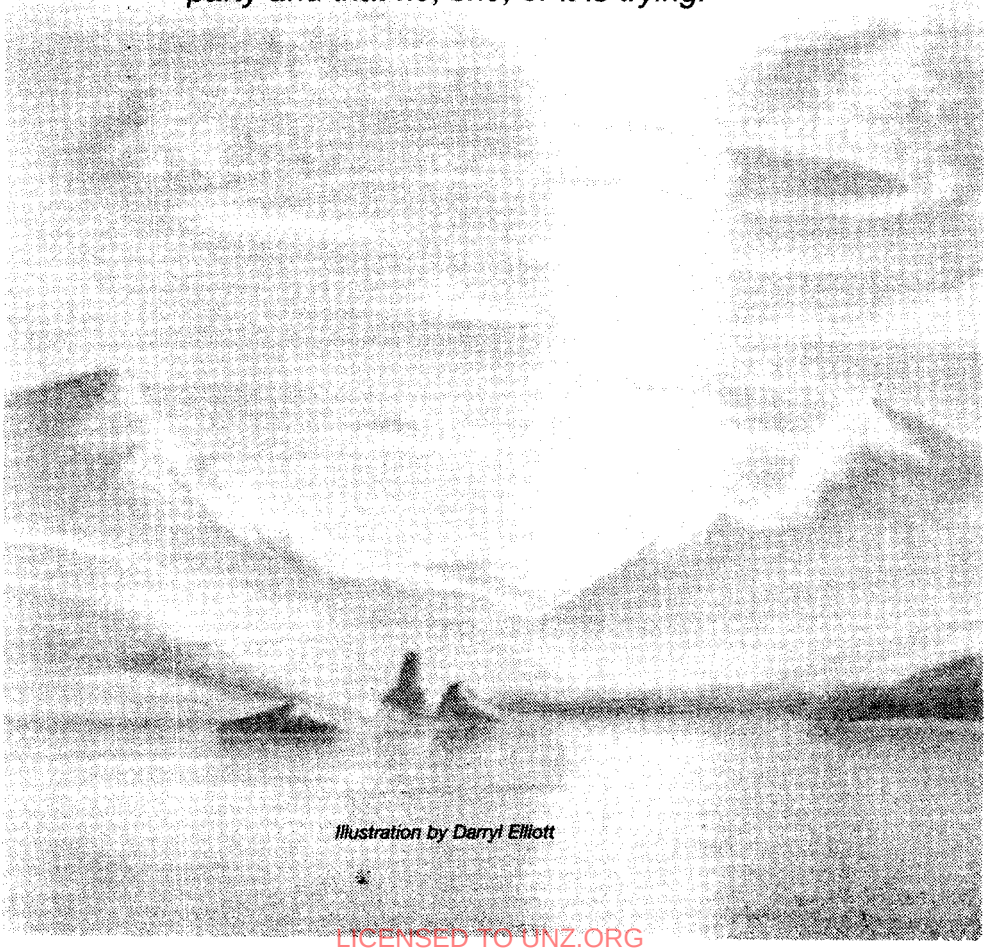

Illustration by Darryl Elliott

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Synopsis

On the planet ***Prokaryon****, all living organisms grow in rings. Tire-shaped zoöids graze over fields of loopleaves, and flyers with helicoid propellers fill the forests of arch-trunked singing-trees. As yet, none of these life forms have shown signs of intelligence; but the forests and fields are spaced in orderly arrays that imply the existence of "hidden masters."*

Prokaryan DNA is triplex, and the biochemistry is full of native structures toxic to humans. To live there, human colonists have to be "life-shaped"—genetically engineered by the ageless Elysians who dominate interstellar trade. Lifeshaping is most successful on infants, whose physiology is immature and could be altered more easily than in adults. Thus Prokaryon has been colonized mainly by children, and by sentient machines. Some Elysian commercial developers want to terraform Prokaryon to make it habitable, though its native ecology—and any hidden intelligence—would be destroyed.

On Prokaryon, a religious order, the Spirit Callers, has founded a colony of orphans rescued from the plague-ridden world of L'li. The colony is run by sentients, the ***Reverend Mother Artemis*** *and* ***Brother Geode****, and by the human* ***Brother Rod****. After years of genetic treatment, Brother Rod can live on Prokaryon without a protective "skinsuit," but he can still only eat imported food.*

As the story opens, Brother Rod and Brother Geode are returning from L'li with four new orphans to join the Spirit Colony. One of the orphans, ***'jum****, is already too mature for easy lifeshaping, and will need to stay many months on* ***Station****, the sentient satellite that prepares visitors for the planet. Her treatment will tax the colony's resources. Brother Rod feels guilty, but knows that the Spirit called him to save her.*

Back at the Spirit Colony, a "tumbleround," a giant Prokaryan plant-animal ridden with insect-sized helicoids, has invaded the garden, and Brother Rod needs to dig the foul-smelling vermin out. Then he finds that the colony's sentient ***Doctor Patella*** *has had an accident and fallen down the side of a mountain where the children mine sapphires. Now, Mother Artemis tells him he will have to take sick children on a journey through the treacherous singing-tree forest to get treatment fro,* ***Sarai****, a reclusive xenobiologist who lives in the mountains. Sarai warns that her own xenobiology research has produced clues to the identity of the "hidden masters," the mysterious intelligent race that manages Prokaryon's climate.*

Most of the research in xenobiology is actually going on at Station, where sentients and graduate students are attempting to communicate with various species to prove that they are the "hidden masters." Rod is skeptical, because the scientists have claimed to communicate with Prokaryan creatures many times before, but it came to nothing. Nonetheless, to earn money that the Spirit Colony desperately needs, Rod signs on to assist the field work of a xenobiology graduate student, ***Khral****. Khral works for Elysium, but her parents were gorilla hybrids, former slaves on a less developed world.*

Khral's theory is that singing-trees use symbiotic "microzoöids," ring-shaped Prokarkyan microbes, to generate messages and transmit through light. She and Rod climb up the singing-trees to collect their lightpods, which contain the light-emitting microzoöids. Khral, unlike Rod, has to wear a skinsuit, an expensive, technologically complex sheath to filter out the planet's toxic chemicals.

In the distance, they catch sight of a starship entering the atmosphere. The ship crashes. It turns out to be a ship of illegal immigrants from L'li. If any passengers survive the crash, without skin-

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suits they will soon die. A friend of Rod's, the corundum miner ***Diorite****, searches the crash site for survivors. Oddly, he finds only the tracks of tumblerounds. Rod wonders about this; he urges Khral to study these plant-animals.*

At Elysium, there are renewed calls to terraform Prokaryon and make a place for impoverished immigrants to go instead of crashing on their own world—an increasing embarrassment. ***Nibur Anaeashon*** *is the chief executive of Proteus Unlimited, a manufacturer of sentient-proof machines; he wants to terraform Prokaryon in order to mine it more efficiently. Nibur convinces banker* ***Iras Letheshon*** *to finance a plan to terraform just one continent, Spirilla. Iras's mate is* ***Verid****, the Secretary of the Free Fold, the highest position in the interplanetary government. Secretary Verid is deeply upset by the plan; but she can offer no alternative measures to help settle L'liite immigrants, nor to halt the plague and end their starvation.*

Meanwhile, Rod is staying at Station to look after 'jum while she is lifeshaped. 'jum has shown antisocial behavior, perhaps caused by her traumatic past; but she also shows signs of an extraordinary gift for mathematics. When Rod returns to the mountains to pick up a child she treated, he introduces 'jum to Sarai. Impressed by 'jum's ability, Sarai reveals her culture of microzoöids that emit pulses of light in prime numbers. Sarai does not tell what creature her microzoöids came from, but she is persuaded to share the culture with Khral.

Khral is annoyed because a local epidemic of "spacer's spit-up" requires her attention. In her spare time she has found that Sarai's microzoöids grow, not in singing- trees, but in tissue extracts from a tumbleround. Perhaps tumblerounds are intelligent; they send the microzoöids to communicate. Alarmed, Rod asks whether the microzoöids can infect humans. Khral assures him that human biochemistry is too toxic for Prokaryan microbes.

At last 'jum's lifeshaping has progressed enough for her to join the Spirit Colony, living in a specially filtered room. Unfortunately she fails to fit in with the other children, only throwing stones at them. Mother Artemis wonders what to do with her. Rod again feels guilty that he saved her, instead of letting her die in peace.

The Spirit Colony learns of Nibur's takeover of their planet. A representative of Proteus Unlimited tells them they will have to relocate to another continent, so that Spirilla can be terraformed. The Spirit Callers are shocked. Reverend Mother Artemis departs to visit Secretary Verid and protest. Though Verid sympathizes, she can only order a temporary stay on the order to move.

Rod and Geode face 'jum's trouble, and the colony's uncertain future. Then Rod is troubled by dreams of Khral. As a Spirit Caller, he must not long for a human lover; yet he cannot stop thinking of her. Brother Geode advises him to meditate in the wilderness. So he goes out alone into the field of loopleaves, where he meets a giant tumbleround. His mind becomes confused and he experiences a strange vision of a hand. Is it a message from the tumbleround?

Unexpectedly Sarai calls the colony. She demands they send her 'jum, as an assistant for her work. Rod at first refuses; but 'jum wants to go. Rod sends the traumatized child, thinking she was no better off at the colony.

Sarai shows 'jum what she has learned of the "language" of the microzoöids. She tells 'jum that the microzoöids were not found in tumbleround; the truth is much worse. Before she can explain, Sarai is interrupted by a call from Proteus, ordering her to leave the continent; Nibur himself will help her relocate her important studies. Sarai refuses to go and warns Nibur to stay off the planet—or he will never leave alive.

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Part 3

CHAPTER 13

As the season entered a gentle summer, twisted red pods ripened in the garden. The nightly rain clouds gathered earlier to shorten the day's heat, and satellites reported the usual shift of major wind systems, bringing cooler air farther south. Rod wondered, how did those tumblerounds control the weather? At a safe distance he watched them, but the lazy plant-animals showed no sign.

He made himself watch the holo broadcast of the Opening of "cleansing" of Spirilla. The event was attended by representatives from Valedon, Bronze Sky and L'li, and the mysterious Elysian director of Proteus Unlimited, Nibur Letheshon. Resplendent in their ceremonial talars, they offered stirring words and bad music, as their satellite hovered above the first land to be "cleansed." An island off the western coast, an aerial view showed two stripes of singing-tree forest.

Beside the holostage, Brother Geode saw Rod clenching and unclenching his fists. His eyestalks lowered. "You know, Brother, we don't really have to watch this."

"It's better to know." Knowledge was better than ignorance—it was never too late to learn. "We can pray for them."

Geode began the standard litany of the Spirit. *Love only truth, desire only grace, know only Spirit.* . . . The prayers expanded to include all the zoöids, large and small, and the hapless singing-trees, and above all, all the participants in this terrible project that unfolded before them.

Above the island, high in the stratosphere, a white whirlwind appeared. It was a tunnel through a space-fold, directed from the sun Iota Pavonis. The sun's heat poured through, turning the whirlwind into a swirl of flame. The flames reached downward as a fountain projected from the ocean. It met the fountain with a roar, creating steam which rained down upon the island. Soon the steam enveloped the island, tactfully obscuring the fate of the landscape.

Geode's blue limb snaked around Rod's arm. "Peace, Brother. We've done all we can; it's the will of the Spirit."

Rod's throat was swollen so he could barely swallow. *The Spirit should grant me a world,* he had once demanded. Now he was losing the one world he had.

"Success!" Nibur Letheshon spoke with authority, with all the kind assurance of a Spirit Father. "This is of course only the beginning. Inland, across the continent, cleansing will probe deep beneath the crust, generating magma chambers to thrust the steam upward." Volcanoes and geysers throughout the fields—the terrain would become unrecognizable. "The cleansing will continue over the next Prokaryan year, reducing the native biota by ninety-nine percent. Then we will seed the crust with thermophiles, microbes that live at steam temperature. The thermophiles will convert all the molecules in the soil to forms compatible with human physiology, while outgrowing the few native organisms that remain."

Bronze Sky, Rod remembered. All of Bronze Sky had been terraformed this way. The resulting vulcanism had colored its sky for centuries.

"In the next stage, we inoculate the land with phase-one human-compatible life forms, including mosses and lichens, annelid worms, and—"

"Brother Rod," called T'kun from outside. "There's a visitor at the door. Hurry."

Rod left the holostage, closing the door behind him to avoid the children seeing such unsettling sights. From the nursery T'kela and Qumum were wailing for attention; he hoisted them up, one in each arm. T'kun whispered, "I don't like this visitor."

"Shh, mind your manners." The outer door was ajar; Rod pushed it out with his elbow. T'kun followed, trying to hide behind him while peeking out to see.

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There stood an octopod. Its gray arms folded about whichever way, without an obvious head. Beyond, next to the llama barn, three more octopods emerged from a lightcraft that bore the cresting wave of Proteus.

"Greetings." The octopod spoke in a monotone, advertising its lack of sentience. "We are here to assist you in relocating to your new homestead in Chiron."

Rod held the children tighter. He resisted the instinct to try a defensive move; no unarmed human could disable an octopod. "Greetings to you, and your master. Please convey our deepest regret, for we do not intend to leave."

The octopod seemed to pause, while the three others stood there threateningly. The babies began to whimper; Rod tried to sooth them. Whatever would those cursed machines do now? Try to take them by force?

"You have received your final thirty-day extension. Use your time well. We will remain available to help you relocate."

Another thirty days—was that from Mother Artemis? Why had she sent no neutrinogram? What if they did not let her return? Most incoming traffic had been canceled. For a free world of the Fold, any halt in traffic would be unthinkable. But Prokaryon was a colony world, subject to the Fold's protection—and its whim.

As Rod came back inside, T'kun asked, "What does it mean, 'relocate'?"

"That's when you move your things to go live somewhere else."

T'kun spread his hands. "Where else is there?" How could they understand? And what choice did they have?

There was no word from Diorite or Feldspar, who were trying to hide in the mountains and force postponement of the cleansing. A few dissidents from New Reyo sent out a manifesto, announcing an underground militia to "fight for independence." Scarcely practical, but it was good to see at least some of the Chiron colonists cared.

At last came a neutrinogram, not from Mother Artemis, but from the Most Reverend Father of the Sacred Order of the Spirit. The bearded Father spoke as always out of the snowy monochrome. "The Spirit be with you, Brother Geode, and Brother Rhodonite," began the Most Reverend Father. "All our sympathy pours out for you, in your hour of trial. Mysterious are the ways of the Spirit; and who can say what our ultimate calling will be? We call on the Spirit to give you all strength in the face of the world's minions.

"Over the centuries, callers of the Spirit have ever been subject to persecution. Our sacred witness ever inspires hatred in those who are deaf to higher things. Pity them, my Brothers. Pity them—and let them have their dominion in this world. It is hard to leave a place of attachment, but you will prosper in your new home. Be sure that all of the Fathers of Dolomoth will hold you up to the Spirit in our hearts."

Rod and Geode sat still for a long while after the message had melted into snow. The message troubled Rod deeply—more for what it lacked than what it said, but he was not about to criticize the Most Reverend Father. Besides, what else could be done? He took a breath. "We have to tell the children."

"Yes, but . . . how do we tell them?"

He thought a moment. "Let's tell the older ones first." They would then help with the young ones.

That evening Rod and Geode met with Haemum and Chae. The rain pattered outside, and a helicoid sought shelter under the window frame. Chae sat straight, a long-legged youth just past his tenth birthday; Haemum was nearing her thirteenth. More adult than children, Rod thought. Geode replayed the neutrinogram for them. The two young colonists watched, their mouths small. When it was over, there was silence. A helicoid in the window scratched at the pane, trying to get in.

"You know what's going on," Rod

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said at last. "The Fold wants us to leave our home."

Chae nodded quickly. "The octopods and all. But Reverend Mother will put a stop to it."

Rod swallowed hard. "The ways of the Spirit can seem obscure at times. Yet even Reverend Mother must obey."

Haemum frowned. "A lot of folks don't like what's going on, even people on Valedon and Bronze Sky. I saw, on the holo. They say it's wrong; that our whole world could die."

"That's good to know. But what they think may not matter in time for our colony."

Silence lengthened. Chae looked down, his forehead knotted in premature wrinkles.

"How can they do it?" Haemum wondered. "All the singing-trees, and all those flocks of helicoids. Even the tumblerounds—Brother Rod, you and I always took such care with them, though we could have used the hide for shoes."

Rod started to smile, then he turned cold. If the tumblerounds grew angry, who would they punish?

Geode's eyestalks twisted and untwisted, then he extended two of his arms. "Sister, you've always done the best you can. It's not your fault; never believe that. It's all a matter of adults. Foolish adults—and even more foolish sentients."

"But what matters is the Spirit," insisted Haemum. "What does the Spirit call on us to do?"

"The Spirit," said Rod, "calls on us to obey worldly authorities."

"Well that's not what how the Spirit calls me." Haemum crossed her arms and her voice hardened. "The Spirit calls me to flee into the forest. The land can't be 'cleansed' before we're found."

Chae nodded. "Me too."

Taken aback, Rod paused. "You are brave indeed; but you'll only gain the few extra days to find you. Think of the little ones."

"Send the little ones back to Station," said Haemum. "The rest of us can hide our tracks by crossing tumbleround territory. Tumblerounds mess up any trail, and their secretions foul nanoplast; even sentients refuse to follow."

Rod glanced at Geode, but his eyestalks only twisted lamely in the face of this insubordination. For a moment Rod wondered. "You have grown into adults, speaking adult words. When Reverend Mother returns, you may tell her your calling."

The next day he began to sort and pack—the lathe and polishers, the grain mill, the few extra clothes. The llamas were another problem; he had no idea how the independent-minded beasts would be moved.

Meanwhile, the sky was crossed by huge transport craft to set up further sites for cleansing all over Spirilla. Their plasma spikes pierced the air, and their sonic booms terrified the children. The little ones had to stay indoors; the sapphire mine lay empty. Octopods stalked the grounds of the colony, as if to intimidate them. Rod's sense of disgust deepened, and something new grew inside him, something he did not like to think about.

As Geode worked beside him, the sentient suddenly came to life. "It's Mother Artemis— I've got her signal!"

"She made it back? Haemum will fetch her—" Rod stopped. The old lightcraft still lay out in the field where it crashed.

"She got a lift—look there!" Above in the sky a plasma spike grew, descending surely to the colony. "It's Quark."

Somehow all the children seemed to know in an instant that Mother Artemis was home, and they came running and crawling outside to see her. Her nanostrands of hair extended to those her arms could not reach.

"Verid said we could stay on," Mother Artemis told Rod, when at last they had a moment to breathe. Her voice alone was such a relief to hear. "I would have sent a neutrinogram, but we need to save expense."

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He shuddered to think what a chunk of their budget her ticket had cost.

"But the octopods gave us thirty days," Geode told her.

"Verid is two hundred light-years away. She warned us things might be made . . . difficult."

Rod added, "The octopods have kept us inside. We can't tend the fields. How can we last?"

She did not answer.

Geode told her, "There's the neutrinogram from the Most Reverend Father."

Mother Artemis viewed the neutrinogram, as best she could with the toddlers creeping up into her lap and down again. When it was over, she nodded slowly. "We will obey. We will pack our things, very slowly. We must live each day here for itself, as if it were our last, and as if we had thousands to come. When the time comes, who knows? The future lies behind a shroud."

Rod clenched his fists. "Haemum and Chae say they have a different 'calling.' They want to escape."

"How wonderful that young adults call for themselves. I will speak with them." She lifted baby T'kela over her shoulder. "This one has certainly grown. How are the others; how is 'jum?"

Geode's eyestalks straightened. "'jum is visiting Sarai—at her request, imagine!" He told the story.

Rod said,"We were short-handed, after all. Now that you're home, we'll fetch her back."

"Is she happy there?" Mother Artemis asked.

"Sarai has not taken calls."

"Then they must both be content. Would they have kept you ignorant, were it otherwise?"

He smiled despite himself.

"Scandalous," muttered Geode. "The last kind of role model 'jum needs."

"We'll see," said Mother Artemis. "For now, at least, Sarai will have to take care of the child's lifeshaping, and save us the expense.

Mother Artemis looked him over carefully. "Brother Rod, are you holding your weight on Prokaryan food?"

"Nearly."

"You must go for your checkup immediately. Take Qumum and T'kela, too; you're all overdue."

Through the rotating connector, Rod held T'kela tight to convince the infant he was not falling into space. Qumum seemed unconcerned, crowing and solemnly examining his fingers. At the gate they met Khral, bearing Quark's eyespeaker; the lightcraft had been running an experiment at Station, all the while during his trip to pick up the colonists. No wonder sentients made humans feel inadequate.

"Look at the babies," Khral exclaimed. "They've grown twice as big." She gave Rod a quick hug, and her cheek brushed his. "You know, Three Crows is just dying to see them again."

"It's a pleasure." Rod hoped he did not look as confused as he felt.

"I'm so sorry about—oh, everything." Her eyelids fluttered beneath her simian brow. "Pushing you all off your own homestead—how could the Fold allow it?"

"For better farmland," he said bitterly. He took a deep breath and tried not to think how her arms had felt around him.

"How is your project, Khral? Are the microzoöids still growing?"

"Which ones?"

"The ones from Sarai. You mean, you have others?"

"Oh, there are thousands of strains. Sarai's strain is a completely new species, unlike those from the singing-tree pods; Elk was quite jealous. We even named the strain for her, *Sarai phycozoöidensis.* That smoothed her feathers a bit. I'm trying to get her up here for a seminar."

Rod smiled despite himself. "Good luck."

"They're growing, all right. We were making *such* progress decoding them, until Station pulled me off the project to isolate that spaceship bug, the one Three Crows got sick on."

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"'Spacer's spit-up,' they call it," chirped Quark at her shoulder.

Khral wrinkled her brow at the eye-speaker. "That's right, rub it in. Anyway—if you've got a moment, I'll show you what we've learned so far."

They entered the laboratory. An oblong vessel of culture stood on a stand, amid several angular instruments. Khral tapped it gently; it shook like gelatin. "That's our tumbleround soup in there—the stuff the microzoöids grow in, remember. They're incredibly active chemically; they put out polymers to gel the whole thing, and excrete all kinds of fibers."

Rod's scalp prickled. "Did you . . . chop up a tumbleround, or what?"

"We snipped a bunch of vegetative root-limbs. You know, the ones the tumbleround extends forward and pulls up behind, as it travels. They break naturally anyhow; the tumbleround doesn't seem to mind. The microzoöids grow well in the stuff, but slowly, by microbial standards—about twenty-four hours to reproduce, a generation time of one day. Anyway, let's magnify them."

She turned to the holostage and dimmed the light. In darkness appeared several blobs of color; Rod counted twelve. Qumum wiggled and stretched to be put down so he could scrabble over to check out something more interesting than his fingers.

"That's okay, he can't hurt anything. Let's get this in focus." The colored blobs sharpened into ringlets, of perceptibly different hues. They seemed to be mainly blues and greens, with one yellow orange. Darker tubes of fibres formed tunnels, connecting among the rings. "I'm going to slow down the time scale of the recording. Watch."

Rod stared until the little rings left afterglow in his eyes. Then the rings started pulsing. No longer continuous, their glow winked in and out so fast he could barely see; but soon the recording slowed.

"You see, it will pulse several times very fast—then stop—then pulse again. Bursts of three, four, five; I've recorded up to twenty at a time. It's their message from the tumbleround."

"Their message? How do you know?"

Khral paused. "I don't know—because I can't read it. It could even be they've given up their message, and what we're getting now is random noise." Her brow creased. "Early on, we got one brief message that was different. I'll show you, but keep quiet about it."

A string of numbers floated through the air: *1, 2, 3, 5, 7, 11, 13* . . .

"A prime series," Rod exclaimed.

"Sh-sh." Khral looked around furtively for watching snake-eggs.

The primes marched on, up till one hundred three. "So that's their message."

Khral shook her head. "It's too simple. A string of primes—so what? Since then, all we get is smaller numbers, a lot of ones and twos, occasional sevens and eights." She shook her head. "Whatever message their masters sent, we lack the key to decode it."

"It doesn't sound like much. How could a microscopic cell ever store a real message?"

"They're large cells, about the size of an ameba. Your own body cells each store six billion 'letters' of DNA—and that's just a linear molecule." Khral turned to the holostage, and it filled with a lattice of molecules. The atoms stacked and connected at right angles in all directions. "Each microzoöid stores a sentient's worth of molecular connections. The molecules can donate or pick up electrons, acting as AND gates or OR gates. Some are switched on by light. A single microzoöid can pack fifty trillion connections, about the number of synapses in a human brain."

A brain's worth of data in a single cell. Rod felt his hair stand on end. "What about the tumblerounds? Did you learn anything?"

Khral half smiled. "I learned why no one else studied them before. Tumblerounds congregate in the singing-tree forest, leaving trails of foul stuff behind—a touch of it got through my skin-

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suit, and the repairs cost twenty thousand credits. They do contain Sarai's strain of microzoöids, about a billion each. Not a lot, by microbial standards. You yourself carry ten thousand times that many bacteria."

"That's comforting. Especially if they keep them to themselves."

"We did learn one thing. The tumblerounds 'transmit' the microzoöids as messages— *through the whirrs!*"

"I thought as much." Rod felt sick. "But messages to whom? How do the tumblerounds *do* anything? How do they tend the land and rule the weather?"

Khral smiled broadly. "The whirrs can carry microzoöids everywhere—even up to the stratosphere. We've done some sampling up there. They probably seed the clouds, or they absorb moisture, depending on how their masters want to direct the air mass. Heck, even on Valedon microbes seed most of the rainfall—blindly, of course." She stepped back to the culture vessel and crossed her arms, staring thoughtfully. "If only I could isolate a pure culture from the whirrs. I've tried, but they just die. They must produce some essential pheromone. Most unusual."

"Why do you need another culture? You have Sarai's culture."

"To study a microbe, you need a genetically pure population, grown from a single ancestor. Otherwise you can have too much variation; maybe even several species, without realizing it," Khral explained. "The only culture we can grow is the original one, from Sarai. We can passage that one, taking about a dozen cells at a time, but never a single cell. Perhaps her culture has aged; like clickflies after a few days, their message may have deteriorated by now. If we can't culture microzoöids directly from the whirrs, how will we ever read their message?"

"What if those whirrs try to 'contact' *us*—more directly?"

Khral frowned thoughtfully. "We still haven't found any micros alive inside a person. But they must be trying. You'd think they'd respond to the—" She shuddered.

"If they are," said Quark, "we sure have no evidence."

"But I have evidence," said Rod.

Khral's eyes widened, and Quark's eye trained on him.

"The Tumbleround—it tried to show me something in my head.

"Something in your head?" repeated Khral.

He wished he could explain better. "It showed me a hand . . . with five fingers."

Quark's eyeball rolled around. "A Spirit Caller's visions don't count as evidence."

"Oh, hush!" Khral gave her shoulder a fierce simian glare. "Have we done much better? Rod—"

"Excuse me." Feeling stung, Rod gathered up the toddler from the holostage. "We have to make our appointments at the clinic."

"Don't mind Quark. Station will run nanos through your veins, just in case. You will be at supper, won't you?"

At the cafeteria, Khral sat with Qumum bouncing on her lap, enabling Rod to manage his food with one arm while T'kela dozed in the other, her arms sticking up straight as only young infants can manage. The tiny holostage played a skeptical report on Khral's work, including some rather crude jokes about the habits of tumblerounds. It listed all the previous "hidden master" candidates over the years: megazoöids, helicoids, and Elk's singing-trees. No wonder all the reporters laughed.

"We've just got to break the code." Khral spooned stir-fry from her plate; like Rod, she invariably ended up with the same item of the table's ten thousand offerings. "We have to convince the Fold they're sentient. I just can't believe Station made me focus on spacer's spit-up instead."

"Can't the medics handle that?"

"They gave up. They called in an epi-

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demiologist from Elysium, but it will take him two weeks to get here. In the meantime, lacking better, it's up to me."

Recalling Mother Artemis's injunction, Rod pressed his thumb to the table and called for a second order of shepherd's pie. "I guess the sickness might be serious."

"Nobody's been sick more than a few days; even Three Crows thinks it's ridiculous. It affects only outbound travelers from Prokaryon, about one in ten, at the moment they try to board a starship. You just sweat and upchuck for a few days—sorry, this isn't talk for supper time."

"No matter." Rod smiled. "I've known worse." From upset stomachs to shoelaces tied to the table legs, supper time at the colony could drive adults to the breaking point. Instead here was Khral; he imagined her in his arms again .... There was no harm in good food and an attractive companion. "Have you made any progress on it?"

Khral brightened visibly; any intellectual challenge seemed to turn her on like a switch. "Well, the medics ruled out all known pathogens. So it must be a toxin of some sort, reacting to who knows what. Change of pressure, perhaps?" She pushed the vegetables around in her plate. "And where does the toxin come from? Maybe from ingested microzoöids."

Rod's fork stopped in mid-air. "But you said they can't grow in humans."

"They can't grow, but they can pass through. Why, they do all the time. Whatever food you eat, you ingest millions of microbes. Everybody does."

That was all he needed to hear. Brokenhearts were hard enough to swallow.

"Most of them have no effect; you're more poisonous to them than they are to you. All that acid in your stomach, and those bile salts in your colon." Khral shuddered. "Enough to do in most of our own microbes, let alone Prokaryan bugs. But a few last long enough to secrete toxins: or maybe the toxins were there in the food already. Like botulin from *Clostridium*."

"So you think it's botulism?"

"Nothing that serious."

What if those whirrs had infected him with enough of the tumbleround's microzoöids to make him hallucinate? "Could insects carry it?"

"Some of the epidemiology suggests an insect vector. There've really been too many whirrs about; even if they don't feed on humans, their propellers could spread something. So we changed *all the filters in the air system, to keep* them out." Khral gulped a forkful. "It didn't help any. In fact, the average duration of symptoms increased from two days to five—probably a statistical fluke."

"But Khral—*what if they're trying to tell us something?*"

Khral did not look up. On her lap Qumum complained for attention, and she shifted him to her other arm. "I had kind of hoped it might turn out that way. But we've found no trace of microzoöids in any patient." She sighed. "It's probably for the best. Suppose 'the masters' really got fed up and sent us a deadly disease. You know what the Fold would do."

Just the excuse they would need. Every colonist had signed the release; Rod never thought much about it, but now he saw how little it would take. "It's always come to that, hasn't it. Valedon ..." Valedon had gone through it, millennia before, the searing of earth and sea, the recolonization. Corn and oak, gulls and skunk; all the living things so dear to his own childhood, lived in place of a lost biosphere. Why skunk? he wondered. Did the old terraformers have their sense of humor—or was it their sense of guilt?

"Bronze Sky, too," said Khral. "Centuries later, it's still cooling down. But my parents came from Urulan to settle there, and I love Bronze Sky as it is now. I live for those speckled hawks, the ones that soar above the geysers—" Khral's look softened, and for a moment Rod

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longed to feel her lips on his. Then her eyes lifted and widened, staring beyond him. "Is that—"

He turned to see. Several headless octopods had entered quietly, limb over limb. Among them passed two Elysians, their trains doubled up behind. The banker, Rod recognized, the immaculate blond president of Bank Helicon. And the master of Proteus, Nibur Letheshon.

The man looked smaller than he seemed on the holo—short of stature, even for an Elysian. He walked slowly, as if in procession, as Elysians generally did, as if to show they had all the time in the Universe.

It occurred to Rod, how little it would take for this small man to breathe his last, and put an end to his schemes. A thumb at the throat would do it. A blow to the temple would do it faster; the twist of a knife, slower.

Rod gripped the table until his knuckles whitened. Then he sank his head in his hands. The colony had nearly lost its home, and what was he doing here? Desiring a woman, and wishing death to a man—how had he come to this? How far could he sink before he lost all sight of the Spirit?

Chapter 14

Nibur kept his promise to Iras, to show her the wilder part of the continent. As his lightcraft from *Proteus* descended toward Mount Anaeon, nothing could mar his good humor, not even the unfamiliar skinsuit that constrained him. He caressed Banga behind the ears; the immortal retriever, too, was enclosed in a skinsuit, and took to it without biting or scratching.

The Opening had gone splendidly, with favorable reviews throughout the Fold. Now all across the continent his earthborers were plunging deep into the crust. By the time the last of the humans had cleared out, and the native biota were duly sampled, the real cleansing could begin. Then the land would fill with lucrative lanthanide mines.

On the slope below, Nibur spotted one of his samplers. "Bring us over close," he ordered. The sampler towered above the trees, where it had selected a choice specimen to transplant. Shuddering, the giant structure poured its nanoplast into the ground surrounding the chosen singing-tree. At last it scooped the tree up, roots and all, and hauled it off for transport.

"Well done," observed Iras. "Your salvage is most efficient."

"Only the best," he agreed.

"I trust you've sampled all thirty-six varieties? At least twenty specimens of each mating type?"

"Twenty-five, in case of losses."

"Excellent." Iras resumed murmuring to her internal nanoservos. Now that the Opening was done, her attention had moved on to her latest project, a new jump station for Solaris, the Fold's most distant world.

As the slope steepened, other samplers appeared, some with various tire-shaped creatures in nets, others full of helicoids. Only one had stalled in those pesky looproots. Nibur's own nanoservos kept in touch with his brain, but his main interest now was the esthetic challenge: to immortalize Spirilla as an incarnation of the *Proteus*.

They at last touched down on the path, as far as the large transport craft seemed safe. To the left rose sheer cliffs; to the right, the underbrush cascaded down to an echoing river. Nibur stepped outside, feeling oddly unclothed without his talar and train, but no matter. An insect alighted, but it could not penetrate the skinsuit. Still, a few odors came through. Nibur took a deep breath through his mouth plate. Ahead of him scampered Banga, sniffing here, there and everywhere. The dog acted as if he had never smelled a scent before. There was little to smell within the *Proteus*.

With Nibur came Iras, and a dozen specially trained octopods fanning out around them, to prevent accidents.

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From around the hill echoed the muffled crunching of the samplers.

Nibur's critical eye scanned the cliffs, which were bursting with unsightly looproots. Those would need to be tidied up in his virtual vision. Ahead of him stretched a gaping valley between Mount Anaeon and Mount Helicon Mountain; an arrangement too shameless for his taste. The mountains would be rearranged so as to appear shyly one by one, for "hide and reveal" experiences. The arching trees, too, would be placed artfully, none too close together, and of course none of the cluttered understory. A few hoopsnakes would be put in to drop from trees now and then, keeping visitors off guard.

"Extraordinary,"exclaimed Iras, craning her neck upward, then down. "The trees—the rushing river—it's enough to take your breath away."

The singing-trees gave way to bushes past their prime of bloom, their browning petals strewn down toward the river. In Nibur's vision, the flowers would be everblooming, with no faded petals. He whispered detailed instructions to his servos recording the scene.

Around the mountain, the waterfall came into view. Nibur stopped. Despite himself, he was impressed. Kilos upon kilos of water tumbling forever out of the mountains, thrusting their steam back upward toward the snow-covered peaks. This scene would be hard to improve.

"Warning," called an octopod from ahead. "The path has changed. Time needed to retrace."

"Very well." Nibur frowned, irritated at the inconvenience. The old Sharer could wait long enough; it was her own fault for refusing contact. He would make good use of his time, recording the mountainside, the chattering of helicoids, and the more graceful varieties of vegetation, all to be sorted later. He whistled for Banga—where had that pesky dog got to?

"Curious." Iras bent down to pluck a leaf. "I thought there were no true 'leaves' on Prokaryon, only loopleaves." She held it out to show him. It certainly looked like an ordinary green leaf, pear-shaped, with branching veins.

"Warning, warning!" One octopod called, then another.

To his horror, Nibur saw an octopod dragged off its feet. Its lasers aimed out in several directions, charring the path. The stench of burnt loopleaves was nauseating. But something twined up to catch the octopod by another limb and flung it down the path. Its nanoplast fell apart into blobs that lost themselves in the brush. Another octopod followed, landing in the arch of a stunted tree. Half its nanoplast split off and crazily tried to climb, losing itself in the loops.

Something tugged at his foot. It was a green vine, with the same pear-shaped leaves. *"By Torr!"* He tried to pull it off, but it held fast. The whole path was criss-crossed with them. The best he could do was to run along with the tugging vine, until it tripped him up and knocked the wind out of him. Sky and mountains lurched around him crazily, as the vine dragged him onward, more slowly now, but still inexorable. Gradually the vines all converged into a huge thicket beside the waterfall.

The vines met, enfolding him into darkness. Then, just as he was convinced he would suffocate, all the vines relaxed their grip and slunk away.

In the darkness Nibur caught his breath. "Emergency, emergency," he gasped. "Bring ten lightcraft with reinforcements, immediately. . . . "

But no answer came. His cerebral nanoservos had no octopods nor lightcraft to contact. He was cut off. He would rather have lost his arms and legs than his link to *Proteus*.

"Nibur?" called Iras from somewhere. "Are you intact, shonsib?"

"Of course I'm intact." Calming himself, Nibur let his breath return to normal. To his right, Banga whimpered for comfort. He was still intact, and *Proteus*

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would find him soon. Then, whoever had done this would pay.

A light filled the cavern. Nibur blinked to adjust, scanning the crystal-studded ceiling of the cave. There stood a naked Sharer with an enormous clickfly perched on her scalp. It was Sarai, the eccentric researcher whose lab he had to relocate. Was this insolence her work?

"You're here," Sarai noted flatly, a clickfly perched on her head. "I would say 'welcome'— but you're not. Be glad you got less than what you gave the western coast."

"You will pay," he exclaimed hoarsely. "You will pay the cost of my octopods— I'll put you out of business."

"Oh, no," said Iras, sweeping forward grandly. "*I'll* pay the damage. Why, Raincloud would have done the same—and my heart hasn't raced so in decades. Sarai—it's you at last! I didn't even have a holo, but you're just as I imagined." Iras stopped, catching sight of a little girl trying to hide behind the Sharer; a L'liite waif. *"Blueskywind!"* she exclaimed at the waif. "Sarai, your ancestor, Raincloud's daughter eight generations back, looked very like her." Iras tossed a holocube to the floor, and the image of another curly-haired waif appeared, playing with a legfish. "You see, you had a non-Sharer ancestor. But she grew up and mated a Sharer, Weena of Shri-el, and their daughter Ryushu . . ." The descendants appeared in succession, each with less hair and more fingerwebs than the last.

Sarai stared open-mouthed at this performance. "Take care, Ushum," she warned the waif beside her. "Elysians are truly mad." But when her own mother and mothersister appeared, she paled, her purple limbs whitening from the fingers upward.

"Oh," said Iras, "don't do that. Or the child will have to wake you." Only a child could safely waken a whitened Sharer. Nibur hoped she died.

Instead, Sarai caught herself, and the purple returned to her limbs. "The two of you are children enough. They should have kept you in the *shon.*"

"Now then." Iras assumed her business voice. "How much will it take to set up your new lab? Will a megacred do, or perhaps ten?"

"Do you think this planet cares about your megacreds? *They* are waiting for you. They've been trying to reach us for years—and finally we hear them."

"Oh yes." Iras suppressed a yawn. "The hidden masters. And who might they be?"

Sarai paused. "Whoever they are, they've gotten their messengers into humans. I know—I can prove it."

"Indeed. Can anyone else?"

Very reluctantly, Sarai said, "The others don't know . . . about the little diving suits the microzoöids wear, to avoid detection."

Nibur laughed. "'Diving suits.' That takes the prize."

"Sarai," said Iras sympathetically. "You really love this world, don't you. Though it's so unlike Shora."

"Most Sharers are fools," said Sarai. "They don't understand what your kind has done to them."

"Sharers understand that no material home is permanent; some day, every raft falls apart in the storm. I've helped many of your sisters find a new home."

"After first destroying their old one?"

"Proteus here," called the nanoservos inside Nibur's head. *"Coming to pick you up, Master."*

"Stay well outside," he warned the calling lightcraft. "We're coming out. Let's go, Iras." He whistled to Banga and strode outside without a glance backward.

In the sunlight his eyes blinked rapidly. He found himself shaking with anger and delayed shock. That such indignities could befall him, his own person, was intolerable. As he glanced around now, at the mountains full of singing-trees, their aspect took on a cast of malevolence. That this world might trip him up—such a thought had never occurred

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to him. But now that it had, he would make his preparations, just in case. A plan shaped itself in his mind, and he whispered brisk instructions. Whatever befell himself, *Proteus* would know what to do. This cursed world would not outlive him.

At the lightcraft Nibur had to whistle three times before the dog obeyed, reluctant to leave this odoriferous place. Nibur grasped his collar and twisted it briefly, to show his annoyance. Iras joined them at last, uncharacteristically silent. As the door closed, their skinsuits opened and crept down their bodies.

"I've been thinking, shonsib," said Iras, as the craft soared toward Station. She did not look at Nibur, but adjusted the folds of her talar after her skinsuit receded. "I'm not so sure that a full cleansing of the continent is really needed. After all, on Urulan, they only cleared the tops of mountains. Here, why not all *but* the mountains?"

His eyes narrowed. "The contract is signed. Is this how Bank Helicon does business?"

"Annihilating unique ecosystems is not good for business. I've heard, from back home." She looked at him. "You haven't answered my question. Why must you clear every last mountain?"

"The poisons wash down from the mountains. The more thorough the cleansing, the greater the yield of the land. Besides, the mountains hide the richest ores." Nibur let his voice soften. "The mountains are important to me, too. But their material existence is nothing. I will create virtual mountains, greater than any on this poor world. They will form my next vision of the *Proteus*. And I will pass the construct on to you—with my compliments."

She did not reply. The offer would be hard to refuse, Nibur knew, for his virtual worlds were one of a kind. Still, for a moment he wished he had taken the bid from the Bank of Bronze Sky instead. They had less capital, but were more predictable.

* * *

When Rod returned to the Spirit Colony, he sought Mother Artemis alone. "I can no longer call the Spirit properly," he told her. "All I can think of is that Elysian, how I wish he were dead."

The Reverend Mother's hair strands knotted and unknotted. "That's too bad. The Elysian could use your prayers."

"If I can't pray for him, how can I pray for anyone?"

She thought about this for some time. From outside, the roar of jet transport set the walls vibrating, as it bore equipment for cleansing to sites across the continent. "Keep trying," she told him. "These things take time. Think of this, Brother Rod: You are being tested."

In the meantime, a tumbleround had migrated to visit yet again, nearly up to the nursery window. No one felt like dealing with it; certainly Rod certainly wanted to keep his distance. So he boarded up the window to keep out the whirrs, and left the beast alone. What matter—they would soon be leaving. On the holo they viewed the site for their new farmstead in Chiron. The land certainly looked similar to their own, the golden ringlets of brokenhearts drooping from their loopstems, the singing-trees stretching alongside the wheelgrass.

The babies fretted, despite Geode's attempts to cheer them, while the older children grew quiet and listless without knowing what was wrong. Gaea took to her old habit of following Rod wherever he went. Haemum and Chae were withdrawn, even surly. They kept up their chores, but Haemum avoided Rod's eye.

One night Rod awoke to hear pounding at the door. He was up in an instant, knowing it would take Brother Geode and Mother Artemis longer to "wake" from their recharge.

There stood two octopods, each with a bundle wrapped up in four arms. One bundle was Haemum; the other was Chae.

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"What have you done to them?" Rod threw himself onto the first octopod and tried to pry the arms of the octopod off of Haemum's face. As his fingers grasped the nanoplast, an electric shock jolted him off. He flew backwards, stunned. Inwardly Rod cursed his own stupidity. His hands and forearms were numb, but with an enormous effort he roused himself to stand.

"The two shonlings tried to escape." The octopod opened its arms, releasing Haemum. She was awake enough to raise herself on her hands. By now Brother Geode had arrived, and he helped her and Chae back inside. Each had a pack of water and medicines; they must have planned their break well.

As Haemum lay exhausted on her bed, Rod found little to say. "It's not easy, Sister, for any of us. But you must trust the Reverend Mother."

Haemum looked up at him. Her eyes were those of a stranger. "What good is Reverend Mother? What good did she do?"

No definite date was set for departure, but the four-eyes meat was gone, and they were dipping into their emergency supply of dried brokenhearts. Every day now the sky was marred by the transporters of death. Whenever Gaea heard it she ran over to cling to Rod's legs.

One afternoon a strange greenish light came in the window. The tint of the sky was somehow familiar to Rod, though he had not seen it in years. He leaned out the window to look.

Iota Pavonis had hid behind a cloud, a dense, round cloud shaped like a pancake. The edges of the cloud ruffled, dissolving and reforming themselves. It was a storm cloud.

Rod could not take his eyes off the sight. He had seen storms in the mountains, and he had heard of weather putting out fires, but this was the first storm cloud he had seen right here at the colony. Its shape was perfectly symmetrical, not like the misshapen storm clouds that used to chase up the Valan coast.

As he watched, a large transport vessel sailed overhead, avoiding the cloud. But as the ship neared, the cloud expanded startlingly. Light flashed, illuminating the depths of the cloud, and thunder rumbled. Out of the cloud snaked a long, gray funnel. With a chilling deliberation, the gray funnel wound its way toward the approaching ship.

Rod ducked just soon enough to avoid the flash in his eyes, as the funnel cloud reached the ship. Above his head the window pane shattered, and his ears rang. He heard children screaming in the next room. Seconds later, there were muffled explosions as parts of the ship hit the ground.

He hurried to check the children, and the other windows. When at last he looked outside again, black smoke was rising over the wreckage of the ship, dampened by a fine mist of rain. The pancake cloud receded slowly, its edges dissolving and shrinking back until it disappeared in the afternoon sun.

Chapter 15

'jum watched Sarai hovering over her pods of microzoöids. As she was taught, 'jum inserted one of the vine tendrils into the pod, to pluck out a microzoöid. It was a tough job, as the microscopic sisterlings had gelled their growth medium and tunneled out little homes to live in. Now the tendril snaked in to find them. The sisterlings always got upset and tried to wriggle away, as 'jum watched their magnified image on the holostage. She selected one, a red-orange ring. The tip of her tendril slithered through the ring hole and captured the sisterling, to be placed under the recorder.

"Find another one right away, Ushum," Sarai reminded her. "Sisterlings get lonely; a single one will pine away and die." Sarai frowned reflectively. "Clickflies don't get lonely. Loneliness takes some intelligence."

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'jum placed another sisterling in the dish, a blue one. Whenever two different-colored sisterlings were put together, their colors immediately shifted until they were the same. Then they flashed very quickly at each other, exchanging bursts of little flashes.

"It's some kind of number code," guessed Sarai. "That's how the little sisterlings talk to each other. They like talking." Sarai flicked her fingerwebs absently across her chin. "But what do they talk *about?*" She gave 'jum an intense look.

'jum had finally figured out who this fish-woman was. As she stood at the cave entrance, looking out over Mount Helicon, it came to her, the memory of that day she had stood outside the shack with her mother lifeless inside. For so many days before she had watched her mother change, from the alert forewoman who bossed the other workers at the Hyalite plant and was assigned to quality control, into an invalid at home, her arms and legs wasting, turning white; turning into a form that did not look at all like the mother 'jum knew. And then, all at once, she had been completely white and still.

But that was not the end. Somehow, 'jum knew, her mother had gone on changing. One of the gods had remade her body; not quite right, just as Brother Rod had not always got things quite right, but they remade her just the same, for all her fish-like hands and feet. 'jum's mother had turned into Sarai.

'jum returned Sarai's hard stare. "Ask them."

Sarai called to the holostage. Instantly it filled with numbers in octal, the system Sharers preferred. These numbers the sisterlings had sent to each other, in little bursts. The numbers were disappointingly small, rarely above ten, and there were lots of zeros.

'jum frowned. "How do you get 'zero' flashes?"

Sarai clasped her hands. "An *intelligent* question—how many years since I heard one! You see, Ushum, the bursts come at regular intervals; yet sometimes the sisterling 'skips' an interval. I'm betting those are zeros." She stared fiercely into the lights. "Pattern, pattern, there must be a pattern." Sarai's jaw fell open. "Look: zero-two-two. It always shows up when sisterling B-eight is one of a pair. Can you find other such correlations, Ushum?"

'jum obligingly went up to the holostage and marked the critical combination with her hand. The numbers set to flashing, wherever they appeared. Sarai clucked her tongue to the clickfly, to record everything 'jum did, not that the girl ever made a mistake.

"Perhaps the sisterlings have names," said Sarai. "Like clickflies do. If they name each other, perhaps they can name things in their growth media. Let's put some fancy molecule in and see what they say. How about anthocyanin? How about some anti-triplex antibiotic, at sub-lethal concentration of course? That ought to get their attention."

By now eight of 'jum's sisterlings swam in the dish of zoöid-phycoid soup. Sarai clucked to a clickfly, who immediately spun a partition across the pod, dividing the group into two groups of four. Into one pod she placed a drop of anthocyanin solution; in the other, the antibiotic specific for microzoöid triplex DNA.

An hour later, she and 'jum were poring over the numbers. "Look at this," Sarai exclaimed. "The patterns are completely different. The microzoöids with the antibiotic produce '*1 0 5 3 0 1*,' over and over again; whereas the anthocyanin . . . it's a longer pattern."

'jum stared, as if nothing existed but those numbers in the air. Her lips moved soundlessly. There was a longer number pattern, including an eight and an eleven, but it only came twice. She felt vaguely disappointed that there were few interesting primes. Still . . . all those zeros intrigued her. What if there were actually a prime series buried underneath?

"Hey, what's this?" Sarai peered at the

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pod. The contents of the half with the antibiotic had liquefied, except for one spot. On the holostage, the four microzoöids had all migrated to one side, leaving a mass of fibers on the other. "That's where I dropped the antibiotic," said Sarai. "They walled it off!" She frowned. "This is altogether too clever—even for clickflies. I wonder." She looked up. "I wonder what their four companions will say, if we 'play back' to them the same sequence of light pulses that these little ones made."

So Sarai spent the rest of the day teaching her vines to pulse photons, with much clucking to the clickflies to insert their DNA signals into the plants. 'jum watched so closely that she began seeing flashing lights inside her own eyes. She blinked several times and finally closed her eyes.

The light was still there, inside her eyelids. How curious. It was flashing so fast she could barely make it out, but then it slowed a bit. It came in little bursts of orange, rather like those ringlets on the holostage.

"At last," exclaimed Sarai.

'jum opened her eyes. Sarai held up two long tendrils of her vine, lifeshaped to produce flashes of light at the tips. The two tips produced the two slightly different wavelengths needed to generate the binary code. These she inserted into the half of the pod receiving anthocyanin, which had remained relatively healthy.

"Now we'll see." Sarai stared fiercely at the holostage. "We'll see what they say to *that*. If they're as bright as clickflies, they ought to respond."

As they waited, a whirr appeared in the air, humming softly. It streaked by 'jum's nose, so close she could see its tiny propeller, then it brushed past Sarai's arm. Sarai waved it away, still watching the holostage.

Another whirr appeared. It spiraled slowly down in the air, hovering at last above the pod of media. Then a second whirr came to join it.

Sarai looked up. "The signal's gone. What happened?" She looked at the pod. "Those infernal insects are eating my microzoöids!"

'jum's lips parted. "I don't think so, Mother. They're just picking them up."

Sarai glared at 'jum. "Whatever do you mean? They just ate every sisterling in the dish. Gone, all of them." She chattered at the clickflies, who set to spinning a fine mesh web across the entrance to the cavern.

"They picked them up," insisted 'jum. "To take them back to their city."

Sarai's eyes narrowed. She looked back at the pod, then at 'jum."Explain yourself, Ushum. Where is this 'city'?"

"The tumbleround." 'jum looked all around the cavern, the clickfly webs, the carnivorous vines to secrete enzymes twisting out from crevices. But there was no tumbleround here. She had not seen one since she left the Spirit Colony.

Sarai came over, bringing her face close to 'jum's. "Why do you call the tumbleround a city?"

"It smells like one."

Sarai took a deep breath; her breasts rose and fell. "Ushum, that is not a logical inference. Insufficient data." She got up and paced back and forth from the holostage to the clickfly webs. "Still . . . suppose it were true." She stopped. "I would be a kidnapper—and a murderer! But no—it can't be. How could microscopic creatures have any brains, when even most full-size humans have so little?"

'jum did not answer. She never had understood the first thing about people, except that few of them in her life were up to much good.

"Experiment, how to design an experiment?" muttered Sarai. "If the sisterlings are only messengers, they certainly are sharp ones—they have hundreds, perhaps thousands of number words. But how could we prove . . . *that they themselves think and feel as we do?*"

The fine mesh web was still forming across the entrance, but not soon

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enough to keep out more whirrs as they appeared. Dozens of them, as if from nowhere, came swarming insistantly, buzzing all around the culture chambers. Sarai closed the open pod, but not before the four were lost. At a command, the main culture vessel was engulfed by a giant flower on one of the vines. The flower closed, its petals tightly wrapped within the calyx, while the whirrs swarmed helplessly around it.

Sarai watched nervously, her hands snapping their fingerwebs. "They know, somehow. They want to get their sisters back."

Suddenly two clickflies sailed in, clicking excitedly.

"What?" Her fingertips paled. "Not here? It can't have got all the way up the mountain." She raced out of the cavern, tearing through the newly spun web. 'jum followed her out the passage, up to the main entrance, where the two clickflies hovered. Sarai took a step outside and craned her neck out, searching down the path. *"Shora*—look!"

A tumbleround was rolling slowly up the path. It was rather a small one, 'jum thought, and it moved along faster than the ones that used to visit the Spirit Colony. She could actually see its foremost tendrils stretch and extend to the ground, implanting themselves, while the hindmost tendrils let go, one by one, whipping upwards as they broke off. A haze of whirrs clouded the creature, and its distinctive odor reached her nose.

"Not here!" Sarai shrieked at the clickflies and tugged at her vines.

The vines came to life, climbing up across the main entrance. 'jum hurriedly stepped backward to avoid them. Within minutes the entrance was thoroughly sealed; not a whirr could get through the packed mass of greenery.

As the cavern sealed, Sarai ran back to her holostage. "Get me the Station lab," she demanded. "That Khral and her dimwit colleagues. I don't care if the line is busy—it's an emergency."

On the holostage appeared a clinic, like the one where 'jum had spent so many unhappy hours. This one however was Khral's place. Khral stood there with the magic eye perched on her shoulder.

"They've found me!" Sarai yelled at the holostage. "You have to get me out of here!"

Khral exchanged a look with the eye. "Who found you? The octopods?"

"The *tumbleround!* They—there's a million of them in there! And they'll know how I've kidnapped and tortured them!"

"Tortured them? A million tumblerounds?"

"They're *inside* the tumbleround. For Torr's sake, just get me out of here."

"Well sure," Khral began, "I don't see why not—"

At her shoulder the eye whispered something.

"Right, Quark," said Khral. "Sarai, we'll take you up to Station—if you promise to give us a research seminar."

Sarai leaned across the holostage. *"I'm invaded by aliens—and you want a research seminar?"*

At Station, the master of *Proteus* was just preparing to depart. His program for Prokaryon was in place, with only a last-minute glitch or two. A few miners remained at large on Spirilla, and the L'liites were still listed as "missing," though they could never have survived; no doubt Verid had kept them listed, always the clever bureaucrat. His contacts at the Secretariat would soon clear that up. More troubling, from a financial point of view, was the sudden weather instability that had cost him some good equipment. Replacement was no problem, but now he would have to arrange some weather control before proceeding. He would eventually write off the expense.

One last neutrinogram arrived, from the Secretary herself. Verid appeared, her owlish shape looking little different in the gray snow than she did in person.

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"Nibur Letheshon, chief executive of Proteus Unlimited," she began in a formal tone. "It is my duty to inform you that your full holdings on Prokaryon, third planet of star Iota Pavonis, now exceed fifty percent. As Fold regulation six-oh-six-seven-three-three of the colonial code prohibits any single corporate entity from ownership of more than fifty percent of a colonial world under Fold protection . . ."

So she found out. Nibur shrugged. He had hoped to postpone detection longer, but it made little difference. He would activate his plans to challenge the claim, in three different world courts. The legal process would take decades to work through, and the regulation might well be changed before then.

"And so," Verid concluded, "we rely upon your high standards of Elysian honor and integrity to rectify the situation and comply with this ruling forthwith." She leaned backward, and her tone changed. "I hear Iras quite enjoyed herself in the mountains. Always the excellent host, my friend. Take care of yourself, dear—and Iras, too."

Irritated, Nibur brushed aside the patronizing remark. He himself had a few last neutrinograms to send, before the express trip home across the space folds. His ship always took the shortest route, although it might cost ten times the fuel.

At last Iras rejoined him, to board the *Proteus*. Their octopods gathered, ready to meet any need. Iras folded up her talar and smiled with amusement. "I trust you scanned clean?"

"Indeed, shonsib, as you did." Even for Elysians, the medics had required extra scans prior to departure, and for his dog as well. Banga now sniffed ahead at the gate to the docking tube, his tail waving.

As the nanoplast of the gate melted in, its edges peeled back to reveal the rotating tube. Nibur caught a handle, bracing himself for the changing forces. Banga stepped forward into the tube. As he did so, the ageless dog gave a yelp and doubled backward, tail between his legs.

Surprised, Nibur caught the dog's collar. Banga was well used to docking tubes; yet now he refused to enter. The artificial gravity must have shifted more suddenly than usual.

Iras had gone ahead, but she stopped and caught her forehead. "Goodness—my nanoservos must be malfunctioning."

With Banga straining at the collar, Nibur took a step forward, then he stopped. His head felt the oddest sensation; there was altogether too little "gravity" here, he thought. Perhaps too little oxygen as well? His stomach convulsed, and a very foul liquid came out; a thing that had never happened to his body before, in five hundred years.

As he tried to cry out, strange glowing shapes appeared. The shapes moved with his head; they must be within his eye, or his brain. From his nanoservos? The shapes formed concentric circles; then they dissolved, and came together to form the letters, *NO*. That was the last he knew before he lost consciousness.

Chapter 16

At the Spirit Colony, the tumbleround had reached the wall outside the nursery and planted its fibers in the siding, reaching just up to the sill of the boarded-up window. The colonists had all their heavy equipment packed and the rest ready to go once their last food ran out. Without fields to tend, at least the children were catching up on their lessons, their math and reading, and their constitutional rights as citizens of the Free Fold. The nationalist protesters could have no complaints now.

"Did you hear," exclaimed Brother Geode, "about that dreadful Proteus person, and his financier? They're both critically ill—with 'spacer's spit-up'!" His eyestalks twisted gleefully, until Rod frowned. "Unlike mortals, who get over it," Geode added, "the Elysians develop complications—meningitis."

"So I've heard." Rod vowed to pray for

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their recovery. "Is the cause still unknown?" Khral must be going crazy over it; she would have no time for tumblerounds now.

"It's a mystery," said Geode. "They tried triplex antibiotics on the dog—and the dog died. Perhaps they'll think again about this planet."

"Perhaps." Rod was uneasy. The very hint of death, even a dog's death, could make Elysians turn the heavens inside out.

That evening as the colonists prayed outside, the llamas calling to the dusk, an occasional whirr strayed over from the tumbleround. Rod found his eyes momentarily clouded with bright, inchoate shapes, reminiscent of his previous encounter with the beast. He shook his head, trying to clear his mind. Should he go up to Station for testing? What could they do for him, if they could not even cure the Elysians?

The next morning, the image of Proteus Unlimited appeared on the holostage. The sexless speaker stood the same as always, above the neverending curl of water.

"Your plans have changed," the speaker announced, as if the colonists had ever made their own plans. The Spirit Callers listened stoically. "You will depart promptly tomorrow. The transport vessel will arrive, at this hour precisely."

So that was it. The children would walk—or be carried out by octopods. Rod kept his face frozen, and his hands at his sides.

Mother Artemis asked, "Is our homestead ready on Chiron? Will the children have a roof over their heads?"

"Unexpected delays have developed. Chiron requires further tests for habitability; it must be cleansed of deadly disease, before any further colonies may be established. We have arranged temporary accommodation of all Prokaryan colonists on an orbital satellite."

A refugee ship. The children would be refugees.

"Once the disease is cleared out, and quarantine is lifted, you will be free to go."

"What do you mean, 'cleared out'?" Rod was shaking. Would the whole world be "cleansed," to eliminate one bit of sickness that endangered only Elysians?

The empty figure did not reply. Geode extended his eyestalks, and some of Mother Artemis's hair outstretched, like a futile plea. "The Spirit be with you," murmured the Reverend Mother at last.

Afterward, she attempted to send a neutrinogram to the Secretariat. She was told the transmitter was out of order. That afternoon, however, a neutrinogram arrived from the Most Reverend Father of Dolomoth.

Out of the snow formed the gray shape of the Most Reverend Father, his beard longer than ever. "The Spirit be with you, Brothers and Sisters," he began. "Our hearts are heavy indeed to hear the sad news from Prokaryon. At least, we thank the Spirit, you were spared the worst afflictions of this deadly plague. Alas, who could have foreseen the unfortunate destiny of your work on that desolate world?

"Remember that you are not the first colonists to have made a valiant effort in a strange new land, only to withdraw from the attempt. You took a courageous stand, and you raised your children well in the light of the Spirit. When you return to Valedon, be assured that the Spirit Fathers will not forsake you. We have excellent spirit-filled orphanages to guide your youngsters to adulthood, at which time they themselves may experience the sacred calling.

"All of the us will call unto the Spirit to give you strength, as you undertake your final journey home."

The brokenheart stew for supper was flavored with helicoids caught from the rafters, since the last of the zoöid meat was gone. As Chae spooned it out down the long tables, Rod still could not believe this would be their last meal in the

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home they had built twelve years before; in fact, their last supper on Prokaryon. Gaea clung to him without eating, and the twins whined.

T'kun popped up from under the table. "Are we going to live in a space ship? Can I bring my pet zoöid?"

Haemum led the prayer, calling the Spirit for truth and grace. Rod found he could not meet her eyes.

After dinner the last of the pots and spoons were packed away. Most of the farm equipment had already been transported—supposedly to Chiron, now no one knew where. Each child kept one treasure: a bit of quartz from the sapphire mine, a helicoid propeller, a dried twisted pod.

As the light faded, the children sat out on the wheelgrass, and Mother Artemis spread her skirt one last time for a story. In the folds of nanoplast shone a planet and a star. The planet was half in darkness, green lapped by tongues of cloud, while its star glowed so brightly it was hard to look upon.

There was a world where only children dwelt. Where every creature grew with a saddle made for riding, and every tree formed little steps for climbing. Every insect came with pinholes ready for pinning into boxes, and a vine grew from every tree for swinging . . . .

The children laughed, and they quickly added others.

"Every zoöid grows a leash for leading," called T'kun.

"And they grow food pods, so we don't have to hunt them."

"And crayons grow on trees."

This world had lived a million years. But its star was growing old and seeing the last of its hydrogen fuel. With its hydrogen gone, the star told the world, "I need to grow. I need to grow enough to burn my next best fuel. But fear not, little world, for you will never die." So the star grew larger and redder. It grew so large that its surface filled the orbit of the tiny world. As the star approached, the world's creatures fell asleep in the heat; until at last the entire world fell into it, dissolving into stardust. But what the star said was true, for that world never died. It will live forever in the hearts of children who remember."

The children grew calm, snuggling close for comfort. Only Haemum and Chae stood aside, their faces sullen. Rod felt torn apart inside. There was love and comfort here, but was there truth? Did the Spirit never call for more?

After the children were in bed, and the last packing done, Rod could not sleep. He stood outside as the nightly rain continued, finally tapering off to reveal the stars. A faint glow came from the distant band of singing-trees, their colors racing across the tops with their enigmatic patterns. Somewhere in the wheelgrass a nocturnal zoöid called for its mate, and another answered. A breeze brought the scent of the tumbleround.

As he watched, an octopod came from behind the llama barn to tour around the main compound, at the same hour it always did. The octopods were highly regular in their habits; their pattern of patrols was familiar to him, their paths crisscrossing the same way every night. Rod reached a decision.

He went inside to find Mother Artemis, now a gray lump sleeping. Regretfully he touched her surface to interrupt her sleep. She came awake slowly, arms extending and hair regenerating out of the amorphous nanoplast.

"Reverend Mother, I must ask your release," Rod told her. "I have called on the Spirit for so many years—but the Spirit who calls back is from this planet. I cannot leave this world here to die, while I return to Valedon."

"Indeed," said Mother Artemis. "You have listened well. But what can you do?"

"I've been watching the octopods. They're only Proteus servos after all, not sentients. I've studied their movements; and I know a few moves myself that might get me past a servo. With your

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permission, I'll leave tonight, hiding my tracks in the trail of the tumbleround." He shuddered, but there was no better way. "By hiding in the wilderness, I can help postpone the final cleansing, while the planet's masters start to fight back. Who knows—perhaps the Fold Council will see reason in time."

She considered this. "If you are called, so be it. But beware. If the authorities capture you, they will not treat you kindly."

"I'll take that risk." One of his more interesting subjects at the Academy had been survival under torture. Students had complained it was outmoded in the age of the Free Fold, but the Academy Master had only smiled.

"Very well," said Mother Artemis. "I think it would be best if I disable the octopods with a stream of radio noise. As you say, they are servos; it may take some time for them to come round and 'repair' my circuit."

Rod swallowed hard. "Thanks," he could barely whisper.

"But first you shall ask Haemum and Chae."

"What? They're children. It's too dangerous. They have lives ahead of them."

"They've earned the choice. It's their planet too."

In the dark nursery, as Haemum and Chae watched, Rod pried the boards off the window, hoping not to wake the little ones. The odor of the tumbleround below was enough to knock him out, but he braced himself to get used to it. A shaft of moonglow fell across Gaea in her bed, her hands stretched before her face with the peaceful abandon of a sleeping child. Rod paused, wondering if he would ever see her again. Mother Artemis was right, he realized; without company, he could never have torn himself away.

Haemum and Chae were poised at the window, backpacks in their arms, awaiting the first step. At last Rod's pocket holostage beeped once; it was the signal from Mother Artemis, disabling the octopods.

Rod crouched on the window, then he leaped forward, out over the tumbleround. He landed in the garden behind it, amid its discarded travel roots. Haemum and Chae tossed the backpacks out to him, including his own which he quickly slipped on. Then they, too, jumped out, and the three of them sprinted down the noxious trail the tumbleround had made through the garden. The gluish secretions got all over their hands and clothes; unpleasant, but any nanoplastic pursuer would avoid their touch.

Ruddy moonglow flooded the fields as if to bathe them in blood. The three of them jogged for a kilometer or so, until the wheelgrass came up again where the tumbleround trail grew old, and they had to pick their feet heavily through. Rod noticed Chae falling behind, and he slowed a bit more. Still there was no sign of pursuit.

A hollow song arose, the manifold voice of the nearest band of singing-trees. The trail of the tumbleround, which had grown faint, seemed to widen and take on fresh odor, as if more than one of the beasts had traveled here. Reluctantly Rod entered the forest, wary of what might drop from the trees. The eerie song of the trees rose to a roar, drowning all else.

They continued through the forest, along tumbleround trails that seemed to cross each other, winding around the great arches of the singing-trees. Rod wondered why no actual tumblerounds appeared. As the night wore on, the singing quieted, and other creatures could be heard. Long squirming rings dangled from the arches, groaning to each other, and the sidling of a hoop-snake gave Rod a start. His toe snagged so often, his hands were cut and bruised from catching himself. He wished they had the sturdy llamas to ride.

Finally the first trace of dawn appeared, from the east behind them. Rod

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called the youngsters to halt. "We'll sleep here, until night falls again."

Haemum nodded without speaking, her face surrounded by matted curls. Chae sank exhausted against the trunk of the singing-tree. What would become of them—such promising students, now stateless refugees. As for himself, Rod could not begin to think of it. Suddenly he remembered 'jum, that day he first found her, alone in the universe amid the hovels of death. Now they were all alone like her.

For the moment, though, the three of them had each other. Rod caught Haemum and Chae each in his arms, and held them both close. He wondered about the others, Mother Artemis and Brother Geode alone with all the little ones, and the llamas—how had they all managed? And where were they now? It was hard to think of the colony deserted and desolate, all their fields of broken-hearts unattended.

He set up the tent in the arch beneath the singing-tree, and the three of them slept until late in the day. In the evening they roused themselves and ate from their packs, sparingly. Haemum found water to boil in the solar unit recharged during the day. Chae caught a hoop-snake to supplement dinner for himself and Haemum; Rod did not yet dare to eat it, lest he sicken without access to help. The gentle twilight rainfall dribbled down their tent as they prayed.

With nightfall, they had to move on, farther along the forest band, to put as much distance as they could between themselves and the pursuers sure to follow. But Chae walked with a limp, though he denied it, and Haemum stopped frequently to press her forehead. "Take one of your medicines," Rod urged.

Haemum shook her head, saying cryptically, "That won't help."

As they slogged on through the loopleaves, the scent of tumblerounds began to grow. They stumbled at last upon a clearing among the singing-trees. Rod stopped, nearly crying out in amazement.

There beneath the star-studded sky were a group of tumblerounds, at least a dozen of them. They were standing quite still, like old truck tires covered with cobwebs.

After staring for a minute, Rod shook himself and turned to the youngsters. "We could rest here a while," he said. "The octopods will avoid this place like the plague." At least he hoped so.

Chae agreed readily, sinking down to rest. Haemum seemed more reluctant, but agreed. Rod wished he could do more for her. He sat himself down against a singing-tree trunk, not admitting the real reason he had stopped.

What if these beasts actually were the masters of Prokaryon? What if he could get across something more from them, more than a raised hand?

Rod watched the tumblerounds, trying to relax and empty his mind as he did when calling the Spirit. For a while nothing happened, and he half slept. Then the bright spots reappeared, shaping themselves in his eyes. They formed random shapes, pinching off and coming together, as if a sculptor were playing with clay. A crude line figure formed, a bar with three branches. Three fingers?

The figure lasted for a minute or so. Then two of the three lines dissolved, and the topmost lengthened above the vertical bar. With a shock, Rod saw that it was the letter "E." Soon it was joined by a "T."

"Haemum," Rod whispered.

"Yes, Brother Rod?"

"Do you ever . . . see odd things? When you get headaches?"

"Maybe," she said guardedly. "Like what?"

"Like letters?" The letter "A" had appeared, followed by "O."

"I've seen letters," she admitted.

"Why didn't you tell us?"

"Chae said you'd think we were crazy."

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Rod looked at Chae.

"We're all crazy," said Chae. "Ever since the tumbleround came after us."

He turned to Haemum. "'E, T, A, O, N . . . .' Does that mean anything?"

Haemum said, "I asked at school. It's the frequency distribution of our language; the most common letters downward." She caught his arm. "How do they do it, Brother Rod? How does a tumbleround . . . get inside our heads like that?"

"They send microzoöids, through the whirrs. Like nanoservos, somehow, the microzoöids contact our brains."

Chae shrunk away. "I always knew those beasts were bad."

Rod remembered the journey to Sarai, when the poor boy awoke to find the whirr-covered visitor leaning over them. "You needn't go through this, Chae. You can go back to Station."

The boy shook his head. "There's bad and worse."

Rod asked Haemum, "Do you ever see words?"

"Once, I think. The word 'the,' the most common word."

So the tumbleround knew about "words"—but it knew no meanings. Did it? How did it know enough to make letters? It must somehow see what his own eyes saw.

From his backpack Rod took a piece of nanoplast that still had enough juice to glow faintly. He pulled out chunks of the nanoplast, which he rolled and stretched into letters, to form the word HAND. He stared at the letters, outstretched on the ground next to his own hand, until his eyes watered. Then he gave up and looked away.

His forehead ached, and the bright rings reappeared in his eyesight. They flickered and coalesced to form the letters: *H . . . A . . . N . . .*

Rod vaguely realized that something of tremendous importance had happened; something the Fold had all sorts of rules and regulations about reporting, if ever such an event should occur to the human race. Except that it never had; and no one cared to believe it now. A Spirit Caller's visions would not count as evidence.

He blinked his eyes, but the letters remained, next to a crude shape of a hand. Why could these creatures not simply announce themselves on the airwaves, he thought, instead of inside his own head? With a sigh, he gathered up the nanoplast, still glowing faintly, and rearranged it to another word: HOME. That was no good; he needed something more concrete. CHILD, he tried, though it was hard to picture a child. LLAMA was a four-legged stick figure. "I" was a man with two legs. YOU . . . . How to picture a tumbleround?

The presence in his head returned, YOU . . . LLAMA.

Rod blinked in surprise. The tumbleround's microzoöids must have picked up "YOU," just from the idea in his head. The "llama" was an understandable error, for Rod himself actually looked four-legged now, as he crouched on the ground. Patiently he reshaped the nanoplast to read: I . . . MAN.

The presence immediately replied: I . . . MAN; YOU . . . LLAMA.

Rod was not sure at all how to take this. Their voices were here inside him, unasked, uninvited. He looked out at the group of tumblerounds, wondering which one of them had sent this message. Or all of them—were they some kind of group mind? And what would the Fold do when they found out?

Chapter 17

At Station, Sarai was giving her public lecture on the holostage. The purple Sharer wore no more than usual, but she carried herself like an Elysian in a full-length train. The viewing chamber was packed with the research scientists, Elk and Khral and the sentients, as well as several caterpillar-shaped medics, who had yet to bring the two Elysians out of their comatose state. Reporter snake eggs hovered overhead like bees, until

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Station warned them to keep out of the way.

In the corner sat 'jum, swinging her legs and feeding bits of protein cake to Sarai's carnivorous vine; it extended only an arm's length, the longest piece Quark could be persuaded to take along. She clucked now and then at the two clickflies working on their web above her head. A reporter tried to interview her for human interest, but she ignored it.

"This species of microzoöid," Sarai began, "*Sarai phycozoöidensis*, was first isolated as silicate particles detected in human cerebrospinal fluid. The silicate coating protects each microzoöid from the toxic human interior, just as our skinsuits protect us from the Prokaryan exterior. Upon removal to standard phycozoöid culture media, the silicate coatings dissolved, to reveal—"

"Whoa, there." Elk half rose to his feet. "Human spinal fluid? I thought your strain first came from a tumbleround—"

Sarai glared. "Is this a seminar or what? *You* can wait till the question period. If I choose to answer any."

Khral tugged Elk's arm, and Quark hissed at him to hush.

Station announced, "We'll have ample time for questions—all day, if necessary. Please proceed."

Sarai sniffed. "Wherever would *I* find a tumbleround; they never reached the mountains until they had to rescue their citizens. As I was saying . . ."

Elk opened his mouth again, but thought better of it. He fell back with a dazed expression.

". . . the silicates from the human cerebrospinal fluid dissolved in the media," Sarai continued, "revealing typical toroid cells, with the usual ring of triplex DNA running around the hole. But these cells failed to thrive. And they were few in number; barely a hundred from the original source." She raised her hand, spreading the fingerwebs like a fan. "That's when I made the ingenious choice of 'universal broth,' a medium of my own invention that enables growth of a wide range of species. I inoculated eight cells. They immediately proceeded to metabolize, putting out all sorts of fascinating by-products." The list of products scrolled down the holostage for the next half hour, while she described them in detail. Elk slumped in his chair, but the medical "caterpillars" reared up to pay attention, for any metabolic product might be toxic to humans.

"On the second day, two individuals fell in love and began to reproduce, by a unique conjugative process." Sarai snapped her fingers at the holostage. Two microzoöids appeared, glowing blue; the two cells came together, neatly stacked. Sarai turned to 'jum. "You're too young for this, Ushum. Go take the clickflies for a stroll."

'jum went on feeding the vine, which had grown about a centimeter so far. 'jum knew pretty well what used to happen between her parents in their corner of the shack, and what happened to girls in the street who didn't throw stones.

"The two ring-like cells fit together, alongside each other," Sarai continued. "Then, all around the ring, the two cells fuse completely."

On the holostage the two rings merged, becoming one.

"Imagine it, if two human lovers became one person with four legs! But each microzoöid is just a cell, remember, with its one ring of triplex DNA. The double cell now has two rings." Within the holographic cell, the two rings of DNA lit up red.

"Since the two enamored cells have become one, their two DNA rings can merge and exchange all six strands. Then they pull apart—in *three* rings of *duplex* DNA." The two red rings came together. Then they split apart into three, presumably three double helices.

Elk jumped up again. "You mean the triplex DNA cells produce *duplex*

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offspring? Two parents make three daughter cells?"

Sarai threw up her hands. "Go ahead, you give the seminar."

Khral pushed Elk's arm. "Never mind, Sarai; we're just trying to follow the evidence. So you observe duplex daughter cells; and then?"

She gave a dark look in Elk's direction. "As our resident genius proposed, each daughter cell grows a third DNA strand right away, restoring the triplex, while enzymes correct all the base-pair mismatches amongst the parental strands, completing genetic recombination throughout the chromosome. Of course the mechanism of recombining triple-stranded DNA molecules is a matter for some speculation. . . ."

She speculated for the next half hour, and one of the medics got up to leave. Sarai glared at the three who remained. "Nano-pushers. No intellectual curiosity, that's what's wrong with the medical profession today. How else will you invent new antibiotics, if not to attack the mechanics of DNA?"

On the holostage the three blue rings began to pulse different colors, while waving their flagella to propel themselves away. "Two parents, three children," said Sarai. "But the interesting point is this: *where are their parents?* Their parents no longer exist, right? Ordinary microbes wouldn't care, but these care a lot." She flicked her webbed hand toward the audience. "Remember, I inoculated with eight individuals, the Sharer way. Not all eight cells reproduced. One of them avoided reproduction, while the others underwent several generations. This one remained, not a parent exactly, but an 'elder' for the young ones. And in all my cultures, the young ones know who their elders are.

"Think of ordinary microbes. What kind of microbes know their parents, let alone their elders? Yeasts bud off daughter cells, and volvox colonies protect their young within the center. But when the young leave, that's it; they never notice their parents again."

Sarai clicked again at the holostage. Numbers filled the air, all the thousands of numbers she and 'jum had studied from the flashing cells. "These microzoöids are different. Their elders pass on their civilization. From the moment of birth, the young microzoöids and their elders flash numbers at each other. At first easy numbers, mainly threes and fives; then larger numbers, even with multiple factors. Those multiple factors are *words.* We even learned two of their words— '*1 0 5 3 0 1*,' for the anti-triplex antibiotic; '*1 0 0 0 3 0 8 0 12 0 2*,' for anthocyanin. Each individual word starts with a number *1*."

'jum had slipped down from her seat and stepped up to the holostage, as if mesmerized. She picked at the digits as if to pluck them from the air, then pointed to other patterns she liked even better. What if each "word" were actually a prime series with holes in it?

"There can be only one conclusion," said Sarai at last. "We're dealing not with the messenger, but with the sisterlings themselves—the true intelligence of Prokaryon. For this insight, of course, I must give credit to my colleague, Ushum."

For a minute after Sarai stopped there was silence, as if the audience could not believe she had quite done. Khral rose and stretched, her legs stiff after the two-hour marathon.

"Just a moment," called Quark's eyespeaker. "There are lots of possible conclusions. How do you even know you've got one species? You're culture may not be pure; you started with eight founders."

"Sharers always start cultures with eight," said Sarai. "So they won't be lonely."

"But—" Quark sputtered but gave up.

Elk rose. "Where do these microzoöids live, if not in a tumbleround?"

"They can adapt to live in almost any host, just as humans can adapt to any

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climate. According to Khral's work, they are more highly concentrated in the tumbleround than anywhere else," she admitted. "We think the tumbleround is their city, their main dwelling place."

"But they could enter the singing-trees too—and control them!" said Elk. "I've checked, now that I know what to look for. The singing-trees could be their long-distance communication!"

"What about *human* hosts?" interrupted one of the medics. "Why and how do these microzoöids cause disease? What's their pathology? Why the onset at entrance to a spaceship?"

"What do you think?" demanded Sarai. "Would *you* like to be carried off from your own universe at a moment's notice, without permission? Wouldn't you try to bail out from your host first?" She added thoughtfully, "Of course . . . all of them might not have bailed out. Some might have stayed on and hitched a ride to the stars . . . within somebody."

"Wait a minute." The next medic reared its caterpillar body. "Are you saying we've got an *intelligent disease* here that's managed to spread undetected—perhaps even to other worlds?"

No one answered. The three medics suddenly slunk out of the room as fast as they could crawl, several reporters in pursuit.

"Wait," Khral called after them. "It's not a 'disease' we're talking about—it's a new sentient race."

Station said, "You're right, Khral; I've notified the Secretariat. But it's a disease, too. Those Elysians are dying."

"How do we talk to them? How do we convince *them* who to talk to?"

Elk said, "After they've tried for decades to contact our own bacteria?" He shook his head. "They must have given up long ago. They must think we have an IQ of zero."

'jum stared. In her eyelids she saw the other lights flashing again. Perhaps she was turning into a holostage—a holostage for the sisterlings inside of her. But how to talk back?

She remembered the vines with the photoemitting tips that Mother Sarai had made to "talk" to the sisterlings in her pod. 'jum had thought of trying those vines before, and now that Mother's attention was diverted, she had her chance. She slipped out of her seat and departed unnoticed. As she was leaving, Khral looked up. "Sarai, you still haven't told us: Who was the carrier? Which human did you get your first culture from?"

Rod awoke with a start. He must have dozed off, but his pocket holostage was beeping. Beside him, Haemum and Chae were fast asleep, too exhausted even to wake. The midday sun filtered through the arches of the singing-trees, and the helicoids cried.

Wondering what to do, Rod frowned at the holostage. Only Mother Artemis had the code to reach him. The holostage beeped again. Very reluctantly he opened the case. "Reception only," he spoke.

In the box two tiny figures appeared; he took a closer look. One was Khral, the other Elk Moon, his tall figure reduced to doll-size.

Rod blinked in surprise. How could she have found him? Was it a trick to capture him—a recorded image?

"Rod? Do you hear us, Rod?" She sounded anxious. "I don't know, Elk; we've got to keep trying." Her head leaned to hear Quark's eyespeaker whisper. The whole lab group, trying to call him?

"Answer, Rod, please. It's about the children."

His hand tightened on the box. "Transmit," he ordered at last.

Khral's eyes widened. "It's you!" the tiny voice gasped. "Thank goodness you're okay."

Rod frowned. "Where did you get my code?"

"From Mother Artemis. We—"

"Is she all right? And all the children?"

"As far as we know. They're—"

Station's voice said, "They're all well, on board our satellite."

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Rod let out a sigh, and for a moment he could not speak.

"They're all . . . well enough." Khral's voice wavered.

Elk added, "Three Crows is helping them out. With the quarantine, now, nobody can leave this place—period. None of us, for Torr knows how long."

"It's horrible," Khral exclaimed. "The Fold has gone crazy—they may kill off this planet, Rod, whether you're there or not."

Rod shrugged. "So be it. What do you need from me?"

"Station said we had to find you," Khral explained, "and Mother Artemis agreed. Rod—there's something else you need to know." She looked uncertainly at Elk.

"It's about the microzoöids," Elk said guardedly. "Khral will explain."

Rod felt he knew more than he wanted already.

"Well," said Khral, "Sarai told us where she got her first culture. She cleared them all out," Khral added hurriedly, "but—" She stopped. "They were in Gaea's spinal fluid."

His mouth fell open. "In Gaea?" He had not expected this at all. "But how—when—"

Khral's face crumpled and she turned away. Elk put his arm around to comfort her. "It's all right," he added. "Sarai promised she cleared them out."

"It was when Gaea was there for lifeshaping, to correct her spina bifida," Khral explained, collecting herself.

"But—*why didn't she tell me?*"

"She doesn't trust you."

Rod remembered that day he arrived, with the two bruised boys and the girl badly in need of care; and how Sarai had made him lose his temper. It had never occurred to him to wonder what she thought of him.

"She checked Gaea's spinal fluids very carefully, and she found these odd silicate crystals, which none of our own nanoservos ever noticed because they weren't programed to do so. Inside the silicate crystals hide themicrozoöids."

Elk added, "You see what that means? We all could be carriers."

"But we're not," Khral added hurriedly. "We're all getting checked, now that we know what to look for."

Quark said, "Even the sentients were all checked, though no silicates have yet been found in us. Not that I'd go near that planet again."

How prudent, Rod thought ironically. "I thought you said it was normal to have a few microzoöids going through your system."

"In the intestinal tract, it's normal to find a few," Khral explained, "but the central nervous system has to be sterile. Infection there causes meningitis—that's what the Elysians got."

"The Elysians are still sick? Why couldn't you clear out the 'silicates'?"

"The medics are afraid to try that. Remember, the triplex antibiotic killed the dog. What would you do, if somebody from 'outside' tried to do you in? It's the microzoöids themselves that are intelligent, Rod."

The microzoöids were intelligent. A brain's worth of data in a single cell. It was senseless; and yet suddenly everything made sense. No wonder the thinking creatures had gone unfound for so long. And now. . . . A chill came over his scalp. How many of them were inside him? Would they not think it right to take his own life, to save so many?

"All the colonists are getting checked now," Khral told him. "Rod, you need to get checked too."

"It's too late. They're in my brain, somewhere. They talk."

"They *what?*"

"They make letters and words."

Khral and Elk exchanged startled glances.

Station's voice took over. "Rod, we need your help. If you've made contact, then Secretary Verid can use you. And we need you to find out what those invaders do when their host tries to board a starship."

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"Wait a minute," Khral interrupted. "Station, you didn't tell me about this. You keep quiet."

"We'll pay you, Rod," continued Station. "Double hazard pay."

"No you won't!" Khral reached for the switch. Elk caught her arm to restrain her, but she pushed him away. "Leave Rod alone, he's been through enough. Holostage—Good bye."

"But the Elysian lives are at stake," said Elk. "The microzoöids might even tell us how to save them."

Station added, "And we'll restore your immigration quota."

The Fold would give anything to save those two foolish Elysians, while half a world could die of prions.

"Leave Rod alone," insisted Khral. "When Secretary Verid gets here, let her decide how to make contact."

Then his inner eye opened, and he saw, as if a light shone, what he was called to do. "I will do it," he said clearly. "I will come back and do what is needed—on one condition. I will take no payments—nothing at all. I will do as I am called, for that reason alone."

Khral's face turned gray. "No, Rod," she whispered. "Not you."

Deep within the sphere of the Secretariat, the Fold Council held an emergency session. Outside, the reporter eggs hovered insistently, but this hearing was closed.

The nanoplastic chamber had shaped itself to make luxurious seats for the delegates, each representing one of the eight peoples of the Fold. Over the council presided the Secretary herself. Outwardly Verid smiled at the delegates, a smile just long enough to meet the occasion. Within herself she burned, like a coal mine on fire underground. Her beloved Iras was dying—half a millennium of their life together, now suspended.

"Citizens." The eight delegates lounged in their eight niches, at various angles and heights within the chamber. "Citizens—we are called into session, at request of the Delegate Elysium."

The Delegate Elysium this decade was her old nemesis, Loris Anaeashon, who had unfortunately succeeded Verid herself as Prime Guardian of Elysium, only to follow her to the Secretariat. A server arm snaked out to offer him a flower cake, while another brought him a pocket holostage.

"The citizens of Elysium demand decisive action against this plague," he proclaimed. "We must eliminate the source of this dreadful pathogen. The policy of partial cleansing was a noble attempt at humane preservation, worthy of the loftiest principles of the Fold. But the hostile weather conditions and the malevolent nature of this plague require decisive action. The planet has been evacuated, the last dissident miners and settlers recovered—the time is now." He raised his butterfly-cloaked arm. "Let the Secretary authorize the full sterilization of planet Iota Pavonis Three."

"Seconded." The Delegate Valedon sat beside him, in a white talar bearing a moon's worth of gems. Both he and the Elysian held substantial stock in Proteus Unlimited.

As Delegate Elysium began his predictable speech in support of the motion, Verid summoned herself out of her private hell. Her keen gaze swept the chamber. Whom might she count on to speak for Prokaryon—and its unknown inhabitants? Delegate Sharer, of course, of the ocean women of 'Shora'; though dwelling on the same planet, they were granted representation separate from Elysium. The Sharer wore a plain talar of purple that matched her complexion, a concession to sensitivities. She would oppose terraforming, as would the Delegate Sentient, a lamppost-shaped creature representing all the sentient machines of the Fold.

Beyond these votes in hand, Verid knew she faced an uphill fight. Delegate Bronze Sky, a shrewd woman as dark as the L'liite, would listen to argument; but

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even Bronze Sky, alas, was a terraformed world. Delegate Solaris, now, from the most remote of the Fold's worlds, was hard to predict. He would take an independent stand, for reasons of his own.

The speech concluded, and Verid looked up. "No one is in a better position than I to sympathize with the intent of this motion." She met the eyes of each delegate in turn. "But since when do we annihilate a whole biosphere, for one fatal disease? Which world of our own could survive such a test?" She shook her head. "More than that—an *intelligent* disease. The duty to respect an alien intelligence forms a cornerstone of the Fold constitution—and for good reason. In respecting 'the other,' we assure respect for ourselves."

Delegate Valedon's seat came alight to respond. "The constitution was never meant to apply to just any old intelligent alien. It was meant for, well, hostile space invaders, that sort of thing. Aliens we could deal with—strike bargains with, buy off, in the usual way. How can you deal with a microbe?" He shrugged. "If you believe they're 'intelligent,' which I don't; it's not yet been proven. Even if they are—all the more reason to get rid of them before we find out."

"Agreed," said Delegate Urulan, an elegant gentlemen with just enough of a thickened brow to keep the simian vote. "The planet holds trillions of them. Should we let our votes be outnumbered a thousand to one by microscopic 'people'? My people won't stand for it."

Though none of this surprised her, a chill ran up her neck. In all our fine clothes, she thought, how little separates us from barbarity. She whispered to recognize the Delegate Sharer, whose seat came alight.

"I will not dignify these arguments with the response they deserve," began the Sharer coldly. "To be outnumbered a thousand to one is nothing new to *my* people. The Sharers of Shora have never, and will never, countenance ecocide." She raised her webbed hand, and its color drained white, the sign of a solemn vow. "If Prokaryon must die, I myself will lead our witnessers to share its death."

At that, the Delegate Elysium turned rigid, though he should have expected as much. Not that a few dead fishwomen would disturb him, but it would be a public embarrassment. "You just wait," he exclaimed, "we'll declare open asylum for immigrants. You can house them all on your rafts."

"The Honorable Delegate will excuse me, but he is out of order," Verid interposed. "Delegate Sentient."

The "lamppost" spoke. "Of course I agree with the Honorable Delegate Sharer. Sentient intelligence is to be recognized—*'in any form it shall appear.'* Those are the words of our constitution. Size is no object—creatures of nanoplast have been recognized as sentient, some as large as entire planets, others as small as insects."

That was true. It was also true, though, that microscopic nanoservos were excluded, by a little-known provision of the treaty.

"I propose a counter-motion: Let the Secretary test the microzoöids for sentience."

Verid nodded, feeling relief; the counter-motion had come as planned. "Let all of us first have their say on the first motion. Delegate L'li."

The L'liite frowned at the Delegate Elysium. "The will of my people is deeply mixed. Indeed, we have to support any measure that opens land for our settlers. Yet 'ecocide' goes against our deepest traditions. Besides, we cannot help but question the economic logic behind this motion. To sterilize Pavonis Three, by a white hole out of deep space, will cost the Fold trillions of credits. A smaller sum could rid my homeworld of the prions that have claimed billions of lives."

As opposed to one dead dog—he might as well have said it aloud. Verid was impressed. She told her internal

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nanoservos to arrange a private meeting with him.

"You're all dreaming," exclaimed the Delegate Solaris. "These are *microbes* we're talking about; microbes that have already escaped within starship passengers, the nine out of ten that *didn't* get sick. They could be hiding *anywhere in the Fold."* He jumped up and spread his hands. "What difference does it make, if we do kill off their planet? They're microbes, with a generation time of only a day. Wherever they are, they'll take over."

Verid observed, "It would make a big difference, I think, if you were a microbe—and you knew who had killed all your family."

"Nonsense," countered Delegate Elysium. "When you have a plague, you wipe out the main source, then control the rest. We can find them; the silicate test has revealed all the carriers."

The seat lighted for the Delegate Bronze Sky. "Are you sure?" The woman rubbed her chin reflectively. "The same researchers who gave us the silicate test believe the disease is intelligent. Smart enough to control all its own animals and plants—even the weather. Think about it. Even ordinary diseases mutate to avoid our tests and cures. We can barely rid a planet of prions, which are mere protein. A disease with intelligence to guide it—perhaps its own 'research program'—will surely come up with novel defenses of its own. To say nothing of malice and retribution. The misery of ordinary disease is a byproduct, an afterthought of its own survival needs. But these, intelligent microbes, what if they contemplate . . . revenge?"

No one had an answer. The delegates sat on in silence. Server arms snaked a cup of water to one, than another.

"What becomes of a pathogen when its host dies?" asked Verid. "What if the microzoöids *need* us alive? Even among ordinary pathogens, the most successful eventually mutate to coexist with the host—millions on our skin, and billions in our intestine. What of an intelligent pathogen who remembers its history and values its host? Our only fatality, so far, is a dead dog." She closed her eyes, thinking, Iras, forgive me.

"Good point," said Delegate Bronze Sky. "At present, we have the upper hand, because they—these 'microzoöids' need to figure out how to use human bodies as hosts without killing us unnecessarily. If we make contact now, they will be well disposed to share all kinds of information about themselves. Newly discovered peoples love to show off."

Verid listened hopefully.

"So doesn't it make sense to authorize the Secretary to test their sentience now? When we have the most to gain?" The Bronze Skyan leaned forward. "Let us pass *both* motions: To contact the microzoöids, and to mobilize a white hole to completely sterilize the planet. Mobilization will take six months, at least; enough time for our medics to come up with defenses, and decide whether destruction is necessary."

And enough time to get the deadly decision postponed or canceled. Verid nodded to herself.

"And enough time for those microbes to take over every planet in the Fold!" Delegate Elysium shook his head. "The white hole won't take six months, only a week. It was mobilized from the beginning, to prepare for just such a contingency."

Verid was shocked. The delegate should not have known about the white hole; it was the most highly classified information in the Fold. Who else knew of it, the secret compromise behind the founding of Prokaryon? Someone, she thought bitterly, had been waiting all this time for the excuse.

"Let's get it over with," said Delegate Valedon. "Eliminate the worst of the contagion, while we still can. We've found all the carriers—isolate them, and study the pathogen."

"Eliminate the carriers, too," said

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Delegate Urulan, "Station and all. They all signed the release."

Delegates Elysium and Valedon looked scandalized, as if to say, *they* were not so barbarous.

"I can't believe my ears," exclaimed the Solarian. "Sterilize a world without a public hearing?"

"It's a crisis. We'll invoke emergency powers."

"To destroy a world before you understand it—such impatience," observed the Sentient. "How typical of humans."

"Delegate L'li," Verid insisted. "What is your view? Should we not take more time?"

The L'liite looked down, clearly troubled. "I'm afraid I must agree that the source of infection needs to be destroyed. In retrospect, I only wish we had done the same with the prions. The prions first appeared in a remote mountain village. Had we cleared the village then, and quarantined those infected, we would be far better off today." He looked up at Verid. "I do agree with the Honorable Delegate Bronze Sky. Let the Secretary make contact, and learn what we can in a week's time. If we turn up anything new. . . ." He did not finish.

"Delegate Bronze Sky." Verid kept her voice level. "Did you intend to leave the Secretary only a week's time to test the microzoöid people?"

The Bronze Skyan considered in silence. With Delegates Sharer, Sentient, and Solarian, she could cast the fourth vote for reprieve, and Verid would break the tie. "The generation time of the microzoöids is only a day," she said at last. "Seven generations should give them enough time to convince us why we should save them." She clasped her hands before her. "I will support both motions—on condition that we meet again, in seven days, to confirm our vote to activate the white hole."

Seven days for Verid to convince the microzoöids she was their best friend, then watch their world die—unless she turned up something to change the vote of the L'liite or the Bronze Skyan.

"We'll give you two extra days first, to reach Prokaryon on the trans-fold express," offered Delegate Elysium. "I'll pick up the cost."

Verid's hands shook. "What if they fight back? Those storms they cause—do you know what kind of energy that takes?"

"All the more reason to act now," said the Bronze Skyan.

"I can't do it,"Verid said. "I have a conflict of interest." They all knew about Iras.

The Sharer said, "You have to, Verid. Because no one else can."

Chapter 18

Into the clearing in the singing-tree forest a lightcraft descended, seeking to land away from the tumblerounds. Rod saw that it was Quark.

"I'm impressed," he told Quark. "You said you'd never touch this world again."

"Somebody had to do it," Quark grumbled. "I told them you all ought to wear skinsuits, but they said it was too late to avoid contamination, and that your microzoöids sound friendly. *Friendly*, indeed."

Rod was suddenly aware of the state he was in. Before, he always wore his robe, and the children their best outfits neatly washed and combed, to visit the satellite. Now the three of them wore travel clothes soiled with tumbleround glue. It was a wonder the lightcraft allowed their feet to touch its nanoplast. "Thanks for coming for us, so many times," said Rod softly. "I'll remember."

The nanoplastic entrance to the lightcraft melded shut. That was it, Rod thought; he might never set foot on Prokaryon again. He held Haemum and Chae close, as together they watch the swirl of Spirilla spiral away, and the planet shrink to moon size in the void. *Farewell, Architeuthis.* . . . He felt vaguely angry at the Reverend Mother's

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stories. Was it right to make a myth out of those one's own race chose to destroy?

As the lightcraft approached the lock, the young colonists picked up their backpacks. Rod tried at least to smooth Chae's hair, and Haemum managed to dig out a comb. But nothing could help the tumbleround smell.

"Don't touch the walls," warned Station. The nanoplastic entrance pulled open about twice as wide as usual. "Proceed immediately to Decontamination."

Just inside the gate waited Khral. Rod stopped. He wanted to accuse her—of what? Of being wrong, or of being right too late? The words froze in his throat. For a moment nothing existed but her eyes. Then he took a step, and she was in his arms. He held her fiercely, as if his hands had taken on a life of their own. Her body melted into his, and her fingers caught his hair. Then he realized that she, too, wanted more than a greeting. *You are being tested. . . .* Slowly he released her, letting his arms fall aside.

"I'm so sorry, about everything. I—"

"It's none of your fault."

"We should have protected the children."

Before he could speak again, Station interrupted. "Proceed to Decontamination."

Khral picked up the backpacks. "Come on, let's keep Station happy. Not that it can make much difference."

"What do you mean?"

"If those microzoöids learn to grow in nanoplast, we're finished. The Fold will incinerate Station, too, along with the planet."

After extensive bathing and disinfecting, the three colonists sat in the clinic while the caterpillar medics injected nanoservos to probe them for silicates. Rod reached Mother Artemis on the holo, at the satellite expansion which housed the rest of Prokaryon's human refugees. Her nanoplastic hair reached toward him, as if to escape. "I have prayed for you without ceasing."

Rod's face twisted, seeking what could not be said in words. "Did everyone get out all right?" he demanded at last. "How are they treating you?"

"We are all well. Three Crows has been a big help to us. He'll stay as long as we need."

He smiled, wondering what Elk would think. The Reverend Mother could have quite an influence on people. "We'll be with you soon."

"Not too soon." The medic arched its long back, waving its forelimbs. "All three of you are carriers. Brother Rhodonite carries the most; at least ten thousand silicates were counted in your cerebrospinal fluid, most of them concentrated around your occipital lobe. Haemum has nearly as many; there's little we can do for her. But Chae has less than a hundred. We've been able to clear that many from a carrier without inducing meningitis."

"That is good," said Station. "After he is cleared, he can rejoin your colony."

Rod patted Chae's shoulder. "You've done a brave job, Brother. The family will be glad to see you again."

Mother Artemis nodded. "You'll return to a hero's welcome"

"I just want to help Prokaryon," Chae said, but he looked enormously relieved.

"Brother Rod," asked Haemum, "what about us?"

"You will join the quarantined sector," said the medic.

"Without whirrs," said Station, "you're not infectious; but we're taking every precaution."

Haemum frowned. "I want to help Brother Rod."

"You've done more than enough, Sister," said Rod. "You need to resume your studies."

For a moment her face took on an expression strikingly like 'jum. "Come on, Chae," she said coldly. "I'm sure the *adults* have everything under control." Rod watched them leave, thinking sadly, how fast they had grown.

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Mother Artemis said, "We know you have a job to do, Rod." Too soon, her image was gone.

Rod thought of something. "What becomes of the silicates that are 'cleared'?"

Station said, "We add them to the cultures."

"Against my better judgement," said the medic suddenly. "Deadly infectious material should be sterilized."

Later in the research lab, Rod asked Khral again about the cultures. Khral shuddered. "They don't survive that long in the cultures either. They need a live host. Let's hope their friends are forgiving. All *we've* lost so far is a dead dog, whereas they . . ."

He did not like the implications. Ten thousand "people" inside his head—how long would he keep them before they found a new home?

In the laboratory, amid the shifting implements of nanoplast, sat 'jum with Sarai's two photo-tipped vines, one in each hand. With her thumbs she covered and uncovered the lights to make them flash. She stared at them fixedly, not looking up even to greet Brother Rod.

Elk was watching her, as he took notes on the holostage. "She says the microzoöids are inside her," the tall Bronze Skyan explained. "We found her like this, 'communicating.' Rather like you did, to teach them our alphabet—except that she learned theirs."

Rod watched with mixed emotions. He still loved the little girl, and he wished she would return him a smile. He admired what she had done, yet he feared for her, and felt ashamed at his failure to protect her. No more prions again, ever, he had promised; but what infected her now was far worse. "Can't you clear her out? She needs to return to the colony."

Sarai stood by the holostage, arms folded across her breasts. "Ushum's work is of critical importance. The sisterlings need her."

"But 'jum is a human child who needs proper care."

Khral caught Sarai's arm before she could reply. "Sarai, remember, Rod is infected, too." She turned to Rod. "'jum carries too many to clear safely. But her microzoöids seem friendly; and she made an important discovery. The microzoöids 'count' by prime factors. Each digit represents multiplicity of each prime factor. Look." The holostage produced a table:

	1	2	3	5	7	11	13	17	19	23	29
1	1										
2	1	1									
3	1	0	1								
4	1	2									
5	1	0	0	1							
6	1	1	1								
7	0	0	0	1							
8	1	3									
9	1	0	2								
10	1	1	0	1							
11	1	0	0	0	0	1					
12	1	2	1								
13	1	0	0	0	0	0	1				
14	1	1	0	0	1						
15	1	0	1	1							
16	1	4	0								
17	1	0	0	0	0	0	0	1			
18	1	1	2								
19	1	0	0	0	0	0	0	0	1		
20	1	2	0	1							
21	1	0	1	0	1						
22	1	1	0	0	0	1					
23	1	0	0	0	0	0	0	0	0	1	

"It's amazing," Khral observed. "Their numbers sort of cycle back on each other, just like—"

"They can count on their fingers for all I care. You can't experiment on a child."

"The Reverend Mother said she could stay." Khral bit her lip. "I'm sorry, Rod. How else will Haemum and the other carriers be saved?"

Elk explained, "Some of the carriers from New Reyo have sickened too, like the Elysians."

Rod felt numb.

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"I don't like it either," Elk added, "but so long as the microzoöids communicate, we need 'jum's help. You see, they work *visually*—whether 'talking' one on one, or sending messages by singing-tree, or hiding in your brain. Your visual system is the one part that makes sense to them. They can 'see' what your eyes see; then they stimulate your brain to 'see' their own signals."

"Excuse me," Station interrupted. "Prepare for Safety Drill. Everyone immediately relocate to your evacuation vessel, for use in an unlikely emergent event."

Sighing, Khral headed for the exit.

Rod tried to nudge 'jum from her seat. At last he carried the potted vine along with her. "I don't remember safety drills," he told Khral. "What's Station thinking? Do the microzoöids have spaceships to attack?"

"We need to be prepared,"said Khral. "In case the microzoöids get into nanoplast. They could wreck Station herself."

He had not thought of that. They reached the lifeship and helped 'jum to climb in. No one would last long, he realized, even in a lifeship. And who would care to pick them up?

"Khral, it's so quiet here now. The reporters—where are all the snake eggs?"

"All sent home, by emergency order. Since then, not a ship can leave."

"I thought the microzoöids bail out when you get near a spaceship."

"Not always. Carriers have been found as far as Valedon and Bronze Sky."

Microzoöids infecting everywhere—the thought chilled him.

"Never fear, Rod," said Khral, "we've got plenty to do before you try the docking tube. A crash course in microzoöid linguistics."

The biologists tried to connect all they knew about the microzoöids' language, from Khral's statistics, from the "words" Sarai and 'jum had identified, and from the messages inside Rod's vision. They probed Rod with nanoservos to report the effects of the microzoöids in his occipital lobe. The holostage produced sentences for Rod to read, alongside flashing number codes that Sarai thought might represent familiar objects—a singing-tree, a zoöid—and activities, such as a person walking or swimming. Several hundred of these were tried, over the course of an hour, but there was no response. Rod found himself wondering if he had only imagined whatever he saw before.

Then, out of the corner of his eye, a light flashed. "There it is," he exclaimed. "A letter will form. . . ."

"Exactly," said Station. "The nanoservos report detecting stimulation of your optical receptors. The microzoöids are responsible, somehow. They must produce neurotransmitters."

Rod read out the response: MAN SWIMS ZOOID—WHO SWIMS LLAMA?

Elk and Khral exchanged looks. "It's gibberish," said Elk.

"Maybe not," said Khral. "A microbe experiences life differently; instead of walking, you swim."

"They don't 'swim' a llama," he objected. "We tested all the llamas, along with the children. The llamas were clear—not a silicate to be found."

"Maybe they use some other kind of 'skinsuit' inside llamas," suggested Khral, "which the medics can't detect."

"Oh, no," said Quark. "Don't say that."

The medic said, "I recommended incineration of all non-human potential carriers."

Rod shuddered. "Where would they get the word 'who'? You never showed them a picture."

Khral thought about this. "Your mind must have formed a picture of it. You must have been wondering 'who?' quite a lot lately."

"You mean they can read my mind—whatever I'm thinking?"

Elk shook his head. "I doubt that. Only things you can visualize."

He closed his eyes. "I'm not sure I can

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handle this," he said, trying to keep his voice steady. "I'd rather have meningitis. You can clear out the silicates, and 'talk' to them in tissue culture."

For a while no one spoke.

"If that's what you want, Rod," said Khral. "I'll direct the nanoservos myself."

Elk looked away, his face creased in pain.

The medic said, "I just left one of the Elysians in critical condition. Without treatment soon, she will deteriorate beyond repair."

Rod took a breath. "Let's get on with it."

"Very well," said Khral. "But Station, we can't just speed up basic research. One word at a time—what else can we do?"

From across the lab came Sarai to check their progress. "Now that we've figured out words and numbers, we're working on chemical names. Ushum has figured out what they call methane and ethane."

Elk gave Sarai a weary glance. "That's great, but how will it help us talk them into leaving us alone?"

Khral said, "Perhaps 'jum's population learns faster." Her eyes widened. "Wait a minute. What if . . . we put the two cultures together?"

Elk caught his fist. "That's it! We remove a few each from Rod and from 'jum, then put them together in media and let them share information."

"Just like we shared with you, Sarai."

Sarai folded her arms. "Ushum's microzoöids seem content where they are. Would they like being kidnapped? Refugees in a culture dish?"

"No time for that approach," said Station. "Let's inoculate a few from 'jum directly into Rod."

The medic reared angrily, waving its eyestalks. "I object! This is completely against regulations."

"It's too much," Elk agreed. "We can't treat people like test tubes."

"I make the regulations here," said Station.

Rod held up his hands. "Never mind. With so many, what's a few more?"

The caterpillar body hunched down. "I withdraw from the case." With that statement, the medic crawled out.

"I'll do the transfer," said Khral quietly, "I'm certified." She coaxed 'jum over to sit by the probe, then directed it to withdraw a dozen silicates from her spinal fluid. Rod watched her expert hands, thick hair down the back of her fingers. Afterward, as she turned to him, her arm was shaking.

Elk said, "We can call one of the other medics."

"Leave them be, the cowards." Khral's voice was short. "The probe will do its work. Rod, you can settle yourself here, while the cell sorter filters out things that would trigger your immune response."

Rod sat next to the probe and looked away as it snaked near his back.

After the transfer his temperature rose and he developed a headache. Station was reluctant to administer drugs that might affect the "visitors" in his brain, so long as his own health was not in danger. He went to bed to rest. Rest did not come easy, though, with a room full of machines sending alarms at his slightest change in blood pressure, He dozed unevenly, dreaming of the long trail before Mount Anaeon, the mist rising forever in the distance, the loopleaves forever tangling his feet.

The afternoon passed, with still no sign from the visitors, new or old. No more lights flashed in his head at all, no matter what he tried to "show" them. The hours passed, and all the researchers could do was wait.

At his bedside, Khral and Quark came to visit. Khral touched his hand. "Are you feeling better, Rod?"

"Much better," he said, not admitting why.

"Rod—you're not mad at us, are you?"

"No. I just wish . . ." For a moment the nanoplastic walls and ceiling all slipped

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away, all just a mistake, corrected. He was back at the homestead the colonists had built with their own hands, the children tugging at his legs, the llamas calling outside, the brokenhearts ready for harvest. Then his eyes focused again, and he half sat up. "What's been happening to the planet?" he demanded. "Have they—"

"They've done nothing." Khral brightened, glad to bring good news. "There were so many incidents with 'bad weather' that they just postponed the cleansing indefinitely."

"They don't admit as much," said Quark, "but they're dead scared. Have you any idea how much power it takes to make a storm appear out of a blue sky? Proteus doesn't know what's going on—nobody does."

Rod sank back again, feeling his prayers were answered. "I just wish I could do a better job for you. Maybe these microzoöids have trouble remembering what they learn, and passing things on, if their generation only lasts a day."

"Oh no," said Khral. "It's true, most of them reproduce within a day, but their 'elders' live on for another month or so. Like Elysians, they choose to live longer, instead of having children of their own."

"Even so," said Quark, "you can see why the ones in the singing-trees lost interest after a month of trying to figure us out."

Rod thought this over. "Station is right; we have little time."

Khral swallowed carefully. "Station wants you to try the docking tube tomorrow morning—whether you've seen any more signals or not."

The docking tube connected to Station at its innermost ring, where centrifugal "gravity" was lightest. Rod approached the gate with Khral, flanked by two medics who had swallowed their principles to attend. He knew his head swarmed with nanoservos, ready to detect whatever the silicate-suited microbes did.

As he approached the gate, his steps slowed. In the smooth face of nanoplast, a dent formed, deepening as usual until a hole opened. Air hissed, as the pressure changed. Was this the signal the microzoöids detected? Rod blinked a few times, but he felt no different. What if they did nothing this time, he wondered. Suppose they wanted to visit the stars?

The hole widened until the nanoplast flattened to floor and ceiling, all around the gateway. Rod could see the usual round tunnel beyond, and he stepped into it. As always the artificial gravity gave a lurch, as the tube began to rotate; Rod gripped a handle for a moment, as he generally did.

Suddenly his head swam, and lights flashed in his eyes. He stumbled back through the gate, where one of the medics caught him. The room spun around him crazily.

"Rod, what's wrong?" called Khral, as if from far away. "Can you see anything?"

One of the medics made an injection in his neck, and his balance stabilized. Rod squeezed his eyes shut, trying to make out the flashing letters. *NO . . . NOT READY.*

"'No, not ready,'" he read aloud. "Not ready for what?" He tried to "see" the letters in his mind.

NOT READY TO LEAVE. LLAMA STAY.

He absorbed this. "I am not a llama," he exclaimed. "A llama is a pack animal. I'm a man." He tried to visualize each word.

YOU ANIMAL. MEN NOT READY TO LEAVE. ANIMAL STAY.

Rod was back in bed, dozing on and off while the instruments profiled his blood, sorted his cells, typed his proteins and did a thousand other things. A tone sounded, and Khral came in. He sat himself up; his head felt not so bad. "Any news? How are the Elysians?"

"We've had a breakthrough." Khral sat by the bed and leaned forward eagerly.

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"Your nanoservos monitored the silicates in your brain, all the while they were acting up. The chemistry gets complicated, but—let's just say the microzoöids had to let down their guard, to put out their neurotransmitters. We figured out a way to neutralize them, so they do no harm as they're removed. We tried it on the sicker Elysian first. If Iras remains stable, we'll try it tomorrow on . . . the other one." The hated creator of Proteus.

Rod sighed. "I'm glad something worked."

"And you? Any change?"

He shrugged. "The letters come back now and then. They call me an 'animal,' and tell me to 'go' and 'stay,' like a dog." For these rude creatures, his children had risked their lives? "I guess this is what it feels like to be a tumbleround, bossed by microzoöids."

"Fascinating . . . that is, I mean, how awful," said Khral. "I don't envy Secretary Verid dealing with them."

He looked up hopefully. "I don't suppose you could . . . well, now that you've figured out how to—"

"Oh yes—we can get them out of you, too, and put them safely in the culture, whether they like it or not." Khral half smiled. "Sarai will have plenty to work with."

The medic returned, rearing its caterpillar-shaped body over the bed to prepare for the spinal tap. Rod rested patiently, thinking how he could rejoin the colony again, free at last of his uninvited guests.

Before his eyes the letters reappeared. STOP. MEN NOT READY TO LEAVE ANIMAL.

Too bad, he thought to himself. Find some zoöid to live in.

ANIMAL WILL LEARN.

Pain filled his skull, spreading throughout his body, as if he were ripped apart very slowly, into very small pieces. Rod gripped his skull, trying to control himself, but it had come on too suddenly. *"Stop, stop."* The pain went on, unending, for hour after hour, the kind of pain he would have severed his own limb to get rid of, except that it was everywhere, in every limb and crevice, within belly and brain.

At last the pain died. Still breathing heavily, Rod looked himself over, his hands and arms, hardly believing he was still intact. "By Torr, that was—" He looked up at the medic still rearing over him, though the instruments had been removed. "Couldn't you hear? What took you so long?"

The medic said, "We required two minutes to withdraw the tap safely."

Two minutes. He looked accusingly at Khral. "I thought you said they could only work with vision. Isn't pain in a different part of the brain?"

"They must have learned something new—something the ones in the Elysian patients don't know yet." She looked at the medic. "Maybe they have research scientists, like us."

"What if their 'scientists' learn more tricks? They could take me over completely."

There was silence.

Station said, "We'll have to figure out how the microzoöids trigger pain."

"Couldn't you just get them out, while I'm under anesthesia?"

Station hesitated. "We might, but what if the pain doesn't stop?"

Rod fell back on the bed and closed his eyes. He tried to recall his Academy drills to endure pain.

The letters returned in his eyes. WELL DONE. ANIMAL LEARNS.

A new sensation filled his mind; a sense of pleasure, unimaginable, beyond what a thousand lovers could give. He floated in it, drifting helplessly as if on an endless sea. Only it came to an end too soon; he begged for it to return, for he would sacrifice anything, even any of the children, to float in that sea again.

His eyes opened. He was damp with perspiration, but otherwise felt fine. Khral and the medic were talking excit-

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edly with Station, as if he were not there. They were helpless, he realized. There was nothing they could do for him. Whatever they learned, the microzoöids learned faster; they would keep ahead, destroying him by inches until there was nothing left.

"Khral." His voice was hoarse. "Khral, listen. You have to help me."

She came over, her face wrinkled. "What can I do?"

"You can give me a 'final friend.' Something to take, in case I have to, before they take me over."

Her eyes widened. "Rod, you know I can't do that. I wish it were me instead, anything—but that I can't do."

"You can," he insisted. "You have all the chemicals. Give me one."

"It's not right." She whispered. "You know it isn't—your Reverend Mother would know."

Rod dug his fingers into the mattress. "What do you know of that? Just give me something, so I can die as a man, not an animal."

Beside the bed, in the nanoplastic wall, a pocket opened. A round tablet came out, the size of his thumb.

Khral stood up. "Station, no!"

"It's your right," Station told him, "by the law. Be careful how you hold that: One squeeze, and it seeps through your skin."

He took the tablet gingerly between two fingers and set it by the bed.

"Don't you tell *me* about being an animal." Khral's simian jaw jutted forward. "Where there's life, there's hope, I say. Must you always be in control?" She stormed out without waiting for reply. Rod remained, one human alone. ■

TO BE CONCLUDED IN THE NEXT ISSUE.

Superstition is plain, downright ignorance. Such beliefs merely shackle the mind and hold you back. Of course, if you break your leg on account of a tortoise-shell cat, that would shackle you even worse, so I keep my eye on them just in case.

— Will Cuppy

It's funny how some of the best thinking about dinosaur shape and dinosaur movement have come from movie artists. Even the 1933 *King Kong* had some brontosaur sequences that were a generation ahead of the dinosaurian dogma taught at the time in universities.

— Robert T. Bakker

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THE QUANTUM ERASER

Tests of quantum phenomena that were previously featured in this column have recently been popping up in the popular press. Early in 1997, physicists in Zurich demonstrated the extent of nonlocality of Einstein-Podolsky-Rosen experiments (see "Einstein's Spooks and Bell's Theorem," *Analog*, January, 1990) using fiber optic cables belonging to the Swiss Telephone System to show the nonlocal correlations of two detectors separated by more than a hundred kilometers. Last December, the first demonstration of the quantum teleportation of photons (see "The Quantum Physics of Teleportation," *Analog*, December, 1993) was performed in Austria. In this column I want to describe another test of quantum mechanics, the quantum eraser, which brings some of the most peculiar and counter-intuitive aspects of the theory into sharp focus.

Richard Feynman observed that if you wish to confront all of the mysteries of quantum mechanics, you have only to study quantum interference in the two-slit experiment. So let's start there. A light source S which emits only one photon at a time illuminates an opaque screen which contains two narrow vertical slits (call the slits A and B) through which the light may pass. Some distance beyond this screen is D, a flat light detector (perhaps photographic film or a silicon CCD) which senses and records the photons of light that pass through the slits and strike it.

In this situation, after enough photons are sent through the slits the detector will record an "interference pattern"—a pattern of vertical stripes of maximum light intensity separated by stripes where there is no intensity at all. Observation of these interference stripes constitutes a quantum measurement, because the distance between the stripes depends on the wavelength of the light. Since the momentum of the individual photons is Planck's constant divided by the wavelength, the interference pattern also measures the momentum of the photons passing through the slits.

The interference pattern is present because light photons are presented with two alternative paths between source and detector, path SAD and path SBD. Quantum mechanics requires that when such alternatives are present, there is a quantum wave function for each, and that these wave functions must be added together (with appropriate phasing) and then squared to predict the outcome of a measurement. In other words, the interference pattern occurs because each photon must pass through both slits en route to the detector, taking path SAD and path SBD. If the difference in length of the two paths puts the wave functions in phase, the waves add and reinforce and a maximum (bright stripe) is produced at the detector. If the difference in path length puts the waves out of phase, the waves subtract and cancel and a minimum (dark stripe) results.

One of the central themes of quantum mechanics is that this interference (reinforcement or cancellation) can happen only because we have no knowledge of whether the photon has taken path SAD or path SBD. If we modify the experiment to detect which slit the photon

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passed through, the stripes of the interference pattern will be replaced by a uniform pattern of light with no maxima and minima.

Suppose, for example, we add a mechanism that covers one of the slits systematically, so that each photon sees only one open slit. In this case there will be no interference pattern. Similarly, if we place polarization-filters over the slits so that one passes vertically polarized light and the other horizontally polarized light there will be no interference pattern (even if polarization at D is not actually measured). This is because a polarization sensitive detector could (in principle) determine which path the photon took. In the famous Bohr-Einstein debate, Einstein suggested a more subtle modification of each slit to sense the slight recoil as a photon passing through it is deflected toward the detector. Bohr demonstrated that this seemingly minimal modification would also destroy the interference pattern.

A trickier version of the two-slit experiment, the "delayed choice" experiment, was proposed by John A. Wheeler. Here, the detector D is mounted so that it can be rapidly retracted. Behind it are two telescopes T_A and T_B, each collimated to see the light passing through only one of the two slits and to detect it with a quantum sensitive photomultiplier tube placed at its image focus. Therefore, detection at D constitutes a measurement of the momentum of the photon, while detection at T_A or T_B measures the position of the photon, i.e., which slit it has passed through.

Such an apparatus is often used to illustrate the wave-particle duality of light. The light waves which form the interference pattern at D must have passed through both slits in order to interfere, while the photon particles which strike the photomultiplier surfaces can have passed only through the single slit at which the telescope was pointed. The position and momentum measurements are "complimentary" in Bohr's sense and mutually exclusive. The uncertainty principle is not violated, however, because only one of the two experiments can be performed on a given photon. But Wheeler is not done yet.

The detector D is mounted on a fast-acting pivot mechanism so that it can on command either be raised into position to intercept the photon or alternatively dropped out of the way so that the photon can proceed to telescopes T_A or T_B. Thus when D is up, we make an interference measurement requiring the photon to pass through both slits. When D is down, we make a position measurement requiring that the photon pass through only one slit.

Wheeler's innovation is this: the time duration required to insure that the photon has safely passed the slits but not yet reached the apparatus is known to the experimenter, and he refrains from deciding which experiment to do. Only after the photon has passed the slit plane does the experimenter decide whether to measure its one slit position (D down) or its two slit momentum (D up). Delayed-choice experiments of this type have actually been performed, and the interference pattern detected when D is up is not affected by the delayed choice. Somehow the photon can retroactively arrange to go through one slit or two depending on which measurement is ultimately made.

The new quantum eraser experiments are high-tech descendents of Wheeler's delayed choice concept. They use a new trick for making "entangled" quantum states. If ultra-violet light from a 351 nanometer (nm) argon-ion laser passes through a $LiIO_3$ crystal, non-linear effects in the crystal can "split" the laser photon into two longer wavelength photons at 633 nm and 789 nm in a process called "down-conversion." These two photons are connected non-locally because they constitute a single "entangled" quantum state. They are required to be in the same state of

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polarization, and a measurement performed on one of the photons affects the outcome of measurements performed on the other (see "Einstein's Spooks and Bell's Theorem," *Analog*, January, 1990).

Further, in a recent version of the experiment performed by a group in Innsbruck, Austria (see reference below), the laser beam is reflected so that it makes two passes through the non-linear crystal, so that an entangled photon pair may be produced in either the first or the second pass. The experiment has the configuration of a six-pointed star formed of three lines (one horizontal and two diagonal) intersecting at a point occupied by the non-linear crystal. The laser beam passes through the crystal moving horizontally downstream, is reflected by a downstream mirror, and passes through the crystal again moving horizontally upstream. Along the two diagonal branches downstream of the laser the two down-converted photons made in the first laser-pass travel to mirrors, where they are reflected back to their production point and travel past it to upstream detectors. The laser beam making its second pass through the crystal has a second chance to make a pair of down-converted photons. If these are produced, they travel directly to the upstream detectors along the two upstream diagonal branches.

The net result is that a photon arriving in coincidence at the two upstream detectors may have been produced in either the first laser pass through the crystal and reflected to the detector or in the second pass and traveled directly to the detector. There is no way of determining which "history" (direct vs. reflected) happened, so the states are superimposed. Therefore, the quantum wave functions describing these two possible production histories must interfere. The interference may be constructive or destructive, depending on the interference phase determined by the downstream path lengths (all about 13 cm), to the three mirrors of the system. Changing the path length to one of the mirrors (perhaps by moving the laser beam reflector) produces a succession of maxima and minima in the detectors. This experimental setup is governed by the same physics as the two-slit experiment, but because there are two coincident photons and well-separated paths for the two possible histories, it is easier to play quantum tricks with the system.

Now the experiment is modified to remove the quantum interference by placing distinguishing labels on the two possible photon histories (direct vs. reflected). A transparent optical element called a "quarter-wave plate" (QWP) is placed in front of one of the photon reflection mirrors. The QWP rotates the polarization state of the reflected photons from vertical to horizontal polarization as they pass twice through it. This polarization modification allows the reflected and direct "histories" to be distinguished, because the reflected photons are horizontally polarized while the direct photons are vertically polarized. Since the two superimposed quantum states are now distinguishable (even if no polarization measurement is actually made) the interference pattern is eliminated, both in the arm of the experiment in which the QWP is placed and also in the other arm, where no modification was made.

Finally, the "quantum eraser" is brought into use. Any vertically or horizontally polarized light beam can be separated into a light component polarized 45° to the left of vertical and a light component polarized 45° to the right of vertical. Therefore, for the photons with the QWP in front of their mirror, placing just in front of their detector a filter which passes only light polarized 45° to the left of vertical "erases" the label that has distinguished the two histories. When this is done, it is found that interference is restored.

Further, the paths to the two detectors can have different lengths, with the

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path through the 45° filter made much longer than the other path. This has the effect of erasing the path-distinguishing label after the other photon has already been detected. This modification has no effect on the interference. The post-facto erasure still restores interference. The path label can be erased retroactively and has the same effect (retroactive or not) on the quantum interference of the waves. Effectively, the quantum eraser *has erased the past!*

It may perhaps seem that the labeling and erasing in one arm of the two-photon experiment could be used to telegraph information to the other arm, with the presence or absence of interference in the second arm acting as a nonlocal faster-than-light signal. Unfortunately for the SF writer looking for a good faster-than-light gimmick, this doesn't work because the interference in the second arm is only observed in coincidence with the detection of a photon in the other arm. Once again, Nature has revealed the power of her FTL telegraph while forbidding us access to the telegraph key.

AV Columns On-line: Electronic reprints of 87 or so past "The Alternate View" columns by John G. Cramer from *Analog* are available on-line on the Web at the URL: http://www.npl.washington.edu/av ■

Reference:
"Complementarity and the Quantum Eraser", T. J. Herzog, et al., *Physical Review Letters* 75, 3034-3037 (1995) and the references contained therein.

Changes

With our current issue, *Analog* goes to a new format which should benefit everybody. It's not a big change—a slight increase in page size—but we have reason to believe it should improve our visibility and sales on newsstands. And there are even more direct and immediate benefits for you, our readers. Even though our new issues will have fewer pages than the old, the new pages hold so much more text that the overall effect is an *increase* in how much we can put it in an issue, equivalent to something like ten pages in the old format. That's enough to accommodate an additional short story in each issue, or a novella where formerly we might have had room only for a novelette. We're quite enthusiastic about the potentials of the new roomier format, and think you will be, too.

Don't miss our other breaking news, either. *Analog* is bringing some of our finest material to you via the Internet. Look for editorials, Reference Libraries, Alternate Views, story excerpts, chats with your favorite authors, and much, much more at our brand-new website, **www.analogsf.com.**

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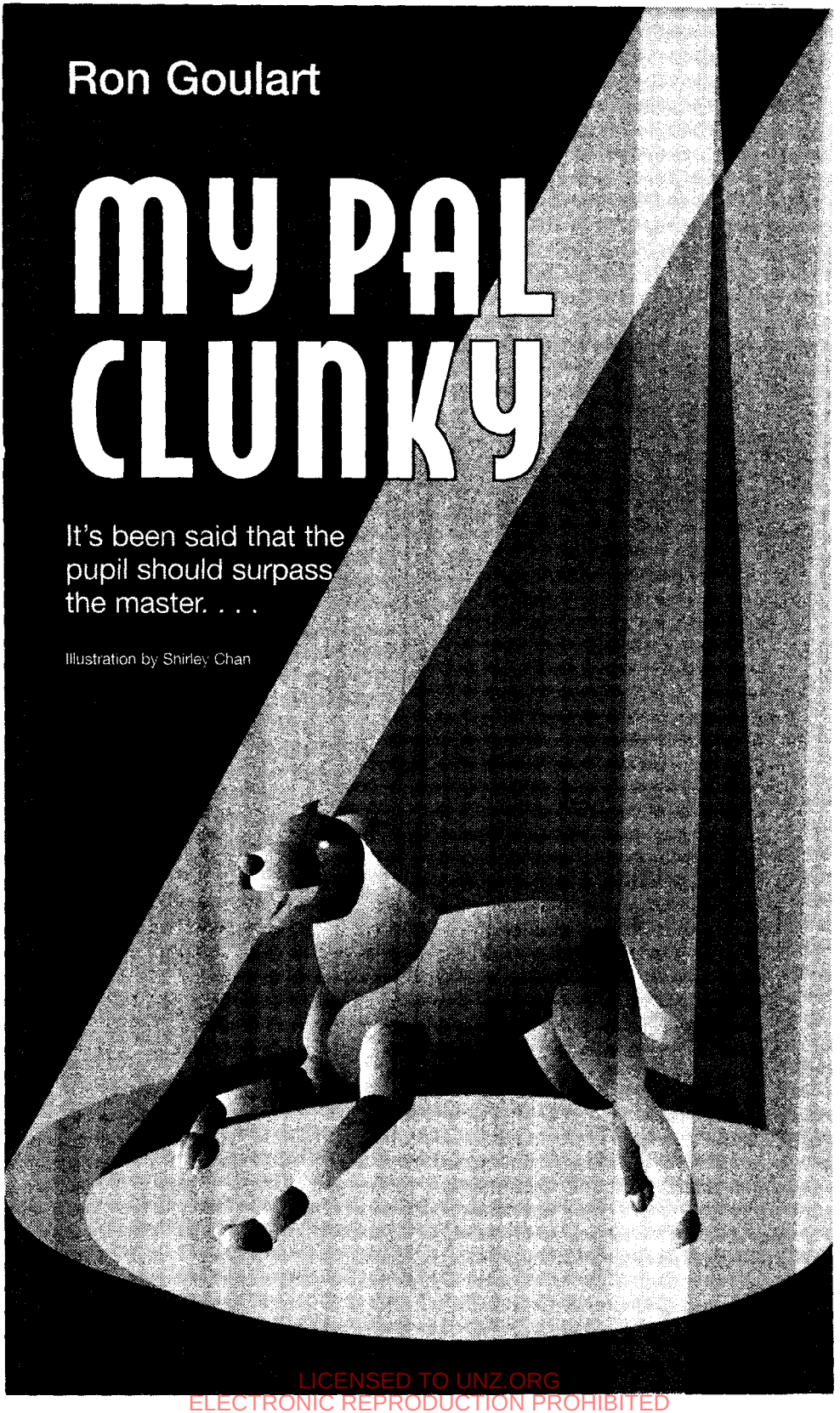
Ron Goulart

MY PAL CLUNKY

It's been said that the pupil should surpass the master. . . .

Illustration by Shirley Chan



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He and the dog sneezed simultaneously.

"God bless," muttered the dog.

Ridge Gilby took a step back from the work bench. "Hey, my DogBots aren't supposed to sneeze," he said, frowning.

The large chrome-plated robot dog was lying on its side, the panel in its midsection dangling open to allow access to the inner circuitry. "Well, that's one of the reasons Mr. Dannenberg returned me for this free overhaul."

Rubbing the plaz handle of the electroscrewer across his slightly plump chin, Gilby said, "It might be better, too, Rex, if you got that snide tone out of your voice."

"That's another reason why I'm here," reminded the silvery Rex. "Didn't you pay attention to the list of complaints Mr. Dannenberg read off to you? He feels, for instance, that a household guard dog should be self-effacing and obsequious with his employer. He further believes that a robot hound who sneezes uncontrollably will have a tough time sneaking up on possible burglars and thieves. It spoils the element of surprise, while—"

"OK, enough," suggested Gilby, sighing. "I really miss show business."

"I'll tell you something," put in Rex, letting his plaz tongue loll out of his metallic mouth for a few seconds. "You'd be a good deal happier if you accepted your fate. Far as the entertainment world is concerned, you're a total flop now and unlikely ever to make a comeback. There are not, as the feller said, second acts in American—"

"Hush," he advised as he thrust the screwdriver into the inner workings of the mechanical guard dog.

The holographic platform in the far corner of the small lab made a muffled pinging sound.

"Oops," said Rex. "Hope it's not another creditor wanting his or her dough."

Very reluctantly, Gilby said, "OK, I accept the call."

The full-size projected image of a young Chinese man appeared on the narrow circular stage. "Hi ya, Mr. Gilby."

Setting aside the screwdriver, he walked over to the stage. "Now what, Eng?"

"Hey, listen, I'd appreciate it if you'd address me as Associate Custodian Eng. What do you think?"

"Now what, Associate Custodian Eng?"

"That sounds better, yeah." Eng grinned. "After all, the Malibu Underground Estates Complex is a high-class, prestigious setup here in Greater LA and—"

"What is the purpose of your call?"

"It's about that dripping in your living room. We—"

"That's not a dripping, it's a small continuous stream."

"Be that as it may," said the Associate Custodian, "it isn't, as you hysterically insinuated when you made your complaint last week, the Pacific Ocean leaking into this underground wing."

"Well, that's a relief. So what the hell is it?"

"Nothing more than a slight malfunction in our highly efficient sewage transfer system," the young man explained.

"Sewage is nearly as toxic as the damned ocean. When are you dimwits going to get this fixed?"

"Hey, labeling me and my colleagues as dimwits isn't going to encourage swiftness."

"When?"

"First thing."

"Which means?"

"Probably tomorrow." He smiled and was gone.

"Hard cheese," commented the sprawled robot dog.

Gilby had taken two steps back toward the work bench when the holostage pinged again.

Murmuring, "Accept the call," he turned to face it.

A plump woman with glittering platinum hair and glowing scarlet lips was

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materializing there. "God, you look terrible, Ridge," she observed. "Your fall from grace hasn't set well on you, dear."

"Edna," he said with minimal enthusiasm.

Edna Thurber spread her arms wide and her image executed a slow turn. "Unlike you, I've been able to afford continuous attendance at one of the best modification spas," she told him. "Consequently, though I'm nearly eighty-three years young, I still look no older than when last we met."

"True," he admitted to his former agent. "Although you do creak more than you did three years ago."

She leaned toward him, smiling. "How'd you like to sign up again with Multimedia Services Worldwide?"

He rested one foot on the edge of the holostage, eyes narrowing. "Somebody's contacted you," he guessed. "Sure, because the last time I tried to reach you I couldn't even get as far as your Assistant Receptionist andy."

"I have put together a rather nice deal for you, ingrate that you are," Edna said. "If you're interested."

"I'm interested in anything that doesn't involve schlepping robotic guard dogs."

"Of course you know Burt Farr."

"Kid actor. We used him on the show couple times."

"No, that was five years ago. Burt's twenty now and just took over as head of the Newgate Network. When Burt was young—"

"He's still young."

"When he was younger, he was a great fan of *My Pal Clunky*."

"So were a couple billion other people around the world."

"The point is, he watched it faithfully. Not just the segments he had small parts on," the plump agent continued. "Burt, darling that he is, thinks it's time for Clunky and you to make a comeback. In his view, there's never been a talking robot dog adventure show to equal it."

"He's absolutely right, and that's because I excel in more than one area," Gilby put in. "I built a truly first-rate mechanical canine. But I was also able to turn out top-drawer scripts for *My Pal Clunky*. The shows mixed action, humor and pathos and those little monologues that Clunky delivered at the tag were—"

"I'm already sold, dear. Save the spiel for the meeting."

"What meeting, Edna?"

"A week from tomorrow you and I, and that darling little Clunky, will shuttle up to the ShowBiz, Inc. orbiting satellite for a meeting with Burt Farr and some of his colleagues. If all goes as well as I expect, we'll—"

"I thought you said the deal was all set?"

"Just about set," she explained. "If it were up to Burt alone, we'd simply sign the contracts to do twenty-six segments of a new *My Pal Clunky* vidwall series, dear. And we'd be pulling in exactly $2,000,000 per episode."

"That's much better than what we were getting for the old shows," he said. "You say this meeting up there is in a week? Could we maybe postpone it for another couple weeks? I've got some guard dog orders backed up and—"

"Eight days, dear. It's either then or never," said Edna. "Oh, say, where is the little dickens?"

"Which little dickens?"

"Well, obviously, schmuck, I mean Clunky. Who else?"

"Oh, Clunky, yes. He's here, sure. Despite the ups and downs and the harsh blows of fate, that marvelous dog and I have remained inseparable."

"I'd like to say hello to him."

"Say hello to him?"

"You've gotten much more slow-witted, dear."

"Actually, Edna, Clunky is up at ground level," he said. "He likes to chase seagulls along the beach. A hobby he's developed since dropping out of the limelight."

"OK, dear, I don't have time to wait around while you go topside and fetch

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him," decided the plump platinum-haired agent. "But give the little bugger a big kiss for me. I'll call you later in the week with firm times for our departure. You're virtually back on top again, Ridge." She made a slight popping sound as her image left the stage.

"Shit." Shoulders slumped, Gilby shuffled over to the work bench.

"Why the gloom?" inquired Rex. "Sounds to me like you're on the comeback trail."

"Unlike you, Clunky wasn't a run of the mill robot dog," said Gilby sadly. "It took me months to put him together and every single component was the best, and the most expensive, to be had at the time." He shook his head and sighed again. "It would take me, even if I could afford it, weeks to build a new Clunky."

"Why do you want to do a dumb thing like that? All you have to do is tune-up the old original Clunky."

Gilby shook his head. "Hell, I sold the old original Clunky over two years ago," he said, "to raise enough money to start this half-wit business."

The lean black man on the vidphone screen was wearing a white medsuit that seemed somewhat loose for him. "What seems to be the trouble? I'm Dr. Mackinson."

"No, you're not Dr. Mackinson." Gilby was leaning far to the left as he faced the phone, careful to avoid the thin stream of processed sewage that was cascading from the living room ceiling into a large plaz bucket. "Mackinson is a big wide Scandinavian gent with an unruly mop of blond hair."

Dr. Mackinson smiled, nodding understandingly. "I bought the Dr. Mackinson franchise for the New Phoenix AZ area well over a year ago," he explained. "I'm the local Dr. Mackinson now."

"Christ," muttered Gilby. "Where's the other Dr. Mackinson?"

"Technically, you see, he isn't Dr. Mackinson anymore. The way the deal works is that in each franchise area there can be only—"

"OK, whoever the hell he is—can you tell me where to find the guy?"

"Perhaps I could help you with this anxiety attack, Mr. Gilby?"

Gilby, slowly and carefully, inhaled and exhaled. He moved a few more inches to the left and tried not to scowl at the phonescreen. "I'm not having a medical problem at the moment, doctor," he explained. "The thing is, I sold something to Dr. Mackinson a couple years—"

"The *former* Dr. Mackinson."

"Him, yeah. I'm eager to locate this object and, if possible—"

"Oh, say, I recognize you now. Even though you're much fatter and pastier than you were back in your heyday," said the black medic. "Ridge Gilby. I have to tell you, I was a great fan of *My Pal Clunky* when I was in med school." He paused, remembering. "Is the Clunky botdog the object you're seeking, Mr. Gilby?"

"Yep. Did he take it with him?"

"No, he sold that appealing little pup to a fellow collector shortly before giving up the practice here—just before he retired to Old New Mexico."

"Sold Clunky to who?"

Dr. Mackinson shook his head. "No idea. I do recall that Sven expressed regret on more than one occasion that he'd been foolhardy in getting rid of such a pleasant and lovable electronic companion."

"I built in those qualities," said Gilby. "OK, is Dr. Mackinson's real first name Sven then?"

"Sven Nordling. He's residing, last I heard, at the Golden Years Chateau Complex in Taos."

"Thanks. I'll try there."

"I can prescribe something for that twitch if you'd like."

"What twitch?"

The doctor tapped his right eyebrow. "A cross between a twitch and a flinch actually. A few swigs of Relaxacon should fix it right up."

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"It's only the sewage that's making me flinch, doctor. But thanks again." He ended the call. "Damn, here's my chance to get out of this lame-brained business and I can't even locate—"

"You ought to turn up the aircirc system to compensate for the reek," suggested Rex from the living room doorway.

"You're not supposed to leave the lab. I'm still working on you."

"Important call for you on the holophone," explained the large silvery dog.

"Bill-collecting bots and andies aren't important."

"This is your ex-wife."

"Which one?"

"Lady who calls herself Molly Spartan."

"Go tell Molly I'll be catching up on her alimony chex very shortly."

"She says she doesn't want money from you just now." Rex nodded back toward the lab. "She says she's calling about making *you* money."

"I'll take the call," he decided.

Molly Spartan was tall and slim; her office was several levels above the ground in the Santa Monica Sector of Greater LA. Red-haired at present, she was just ten years younger than her erstwhile husband. "You ought to rush to a spa as soon as you can," she was telling Gilby as she guided him into a tin client chair and moved around behind her wide Lucite desk. "You're really pasty-faced, Ridge."

"Current medical opinion seems to agree," he said. "If you're finished itemizing my flaws, let's talk about how exactly you're going to make me money."

"You shouldn't ever wear those form-fit tunics," she said as she settled into her chair. "Not with the form you've got."

"Money," he repeated quietly.

"Going to robobarbers again, are you?"

He brushed a hand at his temple. "Molly, you dangled the possibility of my increasing my intake of cash when we spoke this morning."

She looked him up and down and, seemingly with some reluctance, ended her critique. "I've been very successful since we separated," she informed him. "The Spartan Investigation Service is considered one of the best private inquiry agencies in GLA."

"And?"

"In addition to security work and marital cases—I'm an absolute wiz at tracking down people," she said. "I'm confident that I can also find a missing robot dog."

He sat up straight. "How the hell did you know I was looking for Clunky?"

"A man who owes me nearly $13,000 in overdue alimony is someone, Ridge, I'm going to keep an eye on."

"That's not legal, is it?"

Molly smiled, patting the air in front of her as though she were patting his head in a humoring way. "You'll forgive my mentioning this, but you're going about this in your typical incompetent way," she said. "It's extremely dumb, in my opinion, to contact people and blatantly indicate that you're desperate to get that little hound back. What's called for, rather, is an oblique approach."

"Jesus, I am desperate. I've absolutely got to have him up on the ShowBiz satellite in seven days. I don't have time to be oblique."

She steepled her slender fingers, rested her chin on them. "It's possible to be both subtle *and* fast. Want to make a deal with me?"

"Could you, Molly, maybe at least hint at the details of this deal?"

"I help you locate Clunky, negotiate his return to you on the best possible terms."

"And your fee is what?"

"All you have to do is pay the back alimony—with interest," Molly said. "And, soon as the deal with Farr is set, you increase your weekly payments to me by 235 percent."

"Christ, that would amount to—"

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"Or you can forget about Clunky and I'll simply get the law to attach your guard dog setup and pay me out of—"

"I'll accept your onerous terms," he said. "What I was planning to do, once I located the present owner, was to offer him a percentage of the take from the new show for the use of my dog."

"That may not be necessary."

He eyed his former wife. "Do you already know where Clunky is?"

"Not yet, but I'm confident I can run him to ground soon—and I can get his ownership returned to you for as low a price as possible."

He studied her thermocarpet for a few silent seconds. "OK, all right." He stood up and held his hand across the desk. "Shall we shake on the deal?"

"Signing papers will be sufficient," she said, ignoring his hand.

Molly settled back in the pilot seat of her skycar, glancing over at Gilby. "Something?" she inquired.

He was sitting uneasily in the passenger seat. "I've never been that fond of your stunt flying, Molly."

"That wasn't stunt flying just now," she said. "It isn't a stunt when you swoop to avoid a collision."

"Swooping maybe, but the three loops afterwards were—"

"You're even stodgier now than you were during our unfortunate marriage."

He turned his attention to the bright afternoon they were traveling through at an altitude of 5,000 feet. "You're certain Clunky is down here in Florida?"

"Absolutely."

"You haven't," he reminded her, "given me all the details on how you found him."

"When I questioned Sven Nordling's Chief Therapist at the Golden Years Chateau Complex—You ought to take a look at that place, by the way. The residents all have marvelous tans and—"

"I'm only forty-three."

"Really? I thought you were *twenty* years my senior."

"Ten. What did Nordling have to say?"

"Never talked to him directly. Easier, and cheaper, to get the information from a staff person," said Molly. "Turns out Sven sold the robot dog to Greasy Thumb Johnsen down in the Tijuana Sector of GLA."

"Greasy Thumb Johnsen has an unsavory ring to it."

"It's one of those gangster franchises. When the previous Greasy Thumb Johnsen was gunned down in a robobarber shop in the Caliente Sector, the current Greasy Thumb Johnsen bought the role," continued the redheaded investigator. "He was formerly Mr. Soynut in the Pasadena Sector."

"They make second-rate donuts. What does being Greasy Thumb Johnsen entail?"

They were nearing their Florida destination and the skycar began a slow descent.

"He manages the Casa Grande Casino & Bordello in Tijuana."

"He kept my dog in a bordello?"

She nodded. "Actually, Clunky played the piano there and was, according to my sources, extremely popular with the patrons."

He frowned, shaking his head. "No, Clunky can't play the piano. I didn't build that ability into him."

"He can play the piano now, trust me," she told him. "One of my informants raved about his boogie-woogie repertoire especially, and praised his 'wicked left paw.'"

"I don't see how he can—"

"Five months ago a fellow named Prentice Barham from here in the St. Pete Redoubt showed up for a vacation in the Tijuana Sector. He subsequently broke the bank and then, since he'd taken a fancy to Clunky, bought him from Greasy Thumb Johnsen."

"Clunky's still in his possession?"

"That's what Barham's butler tells me, yes."

"If Barham is living off a gambling for-

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tune, he's not likely to sell me back my robot dog for anything like a reasonable price, Molly."

"Let me worry about the business details," she suggested. "I did some research on Barham and I think I'll be able to persuade him to sell cheaply."

The voxbox on the dash panel of the descending skycar announced, "We'll be arriving at the villa in two minutes eleven sections."

Gilby asked, "Villa?"

"Barham bought that soon after he bought your dog."

The cyborg butler bowed, then gestured with his coppery right hand. "If you'll step into the music room, please," he invited Molly and Gilby.

The villa consisted of a linked series of five huge plazglass domes, each tinted a different pastel shade. There were holographic tropical plants and trees lining every passway and the aircirc system was pumping in a steamy scent reminiscent of damp greenhouses.

The music room was in the dome that was tinted a pale turquoise and someone within it was playing the *Goldberg Variations* on an electric harpsichord.

The butler halted at the entry way, stood aside and said, "In there, if you will."

"Hi, kiddo," called the small silver-plated robot dog who was sitting on the harpsichord bench. He remained in an awkward, vaguely human position until he'd concluded the seventeenth variation. "Long time no see, Ridge old boy."

"You can't play the piano." Gilby moved nearer his creation.

"This happens to be a harpsichord, chump." The dog hopped free of the bench, went trotting over to Molly. "Hi, toots, you're still gorgeous. Which is more than I can say for Young Tom Edison yonder. You've got a complexion like unbaked sourdough, chief."

"So I keep hearing." Gilby scanned the room.

There were two pianos, one traditional and the other electric, a harp, two dozen or more simulated potted palms, Victorian-style furniture and, on a low pedestal, a neomarble statue of Clunky up on his hind legs with one paw to his brow and apparently looking far off.

"Pipe the sculpture, folks," Clunky invited. "Me in a heroic pose. Nifty, huh?" He circled Molly once before jumping up onto a candy-stripe loveseat and stretching out.

"Why would Prentice Barham want such a godawful artifact in his music room?" asked Gilby, frowning at the statue.

The robot dog snickered. "Dumb as ever, I note," *he said to Molly.*

"Meaning," she said, "there is no Prentice Barham?"

"Bingo," said the dog. "Park it, folks, and we'll chat for a spell."

Gilby sat on the edge of a Morris chair. "But Prentice Barham is the guy who broke the bank and bought you from Greasy Thumb Johnsen."

"Yeah, sure, and Snow White shacked up with Prince Charming and lived happily ever after." Clunky sighed. "Barham was actually a down and out vidwall actor I hired for the part. He strolled into the casino and I rigged the wheel so he'd keep winning. Then he bought me my freedom and I gave the poor gink his 10 percent of the take." The robot dog sat up, rolling his plaz eyes. "I own this joint and, since I've invested wisely, I'm set for life."

"A dog can't own property or—"

"I'm no ordinary mutt, remember? Besides everything was done in the name of Prentice Barham." Chuckling, Clunky rolled over on his silver-plated back. "I've been thinking about giving you a jingle on the vidphone, boss. It's just about time for a tune-up and you might—"

"Don't you miss acting, Clunky?" asked Molly from another loveseat.

"Do you miss slipping between the sheets with the human pudding yonder?"

"Well, no, but acting on a vidwall show is exciting."

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Gilby scowled. "How come every discussion tends to involve insulting me in—"

"Ah, I get it. Sure, you dimwits invaded my privacy in order to try to persuade me to jaunt up to the Show Biz satellite with you next week." Clunky chuckled again.

"They're offering $2,000,000 per show," said Gilby.

"And my cut will be?"

"You never got a cut on the old show and—"

"Nix, old boy," cut in the robot dog. "I'm no longer the same naïve little mechanism you cooked up years back. Nope, I've improved myself immeasurably, boss, made additions, modifications and—"

"You couldn't have done that, Clunky. It would be a violation of the basic laws of robotics."

"Nertz to the basic laws of robotics." He dropped to the real tile floor and trotted over to where Gilby was sitting. "Fifty-fifty."

"Hum?"

"I have to get 50 percent of the gross take."

"Why's a dog need $1,000,000 a week?"

"Same reason you need it, boss." Clunky looked up at him with narrowed plaz eyes. "Well?"

After a moment Gilby said, "OK, it's a deal. But it hurts me deeply to realize that the very creature I labored over for endless trying months could now—"

The robot dog made a raspberry sound. "Hey, this is show business we're talking about," he reminded. "Hardly the place for sentimental guff."

Clunky leaped up onto the big oval conference table, landing with an echoing thunk. He rose on his hind legs and executed an expert cakewalk. "Greetings, ladies and gents," he said to the three executives seated at the table.

Gilby came hurrying across the domed satellite room after the robot dog. "You'll have to excuse Clunky," he said, making a grab at him. "He's excited about the possibility of returning to—"

"Howdy, Burtie." The dog eluded his creator, skidded across the tabletop and landed in the lap of the youthful Burt Farr. "You're a lot better looking than you were as a kid actor. Although that's not saying much."

"Good to see you again, Clunker," the thin blond Farr said as he pried the dog off his lap and deposited him again atop the table.

Clunky took a couple of steps, then executed a bird-dog take. "Wellsir, if it isn't Rowland Hemerson," he said, nose aimed at a large, wide man of fifty. "Haven't seen you since—"

"You've never seen me, you odious little mutt." Hemerson pushed his chair back several inches.

"I get you." When Clunky winked, his metallic eyelid produced a loud clicking sound.

The thin black woman sitting on the opposite side of the table cleared her throat. "I'm terribly afraid, Mr. Gilby, that you've had to make the shuttle trip up here for nothing."'

"How's that, Mrs. Leandro?"

"Burt was a little premature in what he told your wonderfully well-preserved agent," she said. "We've decided—unfortunately too late to prevent you from making the journey here—that we won't be able to make an offer on *My Pal Clunky*."

"I'm still very enthusiastic," put in young Farr. "Probably within another year or so—"

"Boss," suggested Clunky over his silvery shoulder, "why don't you go out and join your former missus in that gaudy reception room?"

"I don't intend to leave you alone with—"

"Scram and trust me."

Mrs. Leandro said, "There's really no need for either of you to remain any longer."

Ignoring her, the dog said, "Chief, please. Scoot."

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With a lopsided shrug, Gilby made his exit.

The suite they had on the Earthbound shuttle was twice the size of the one they'd occupied on the trip up to the satellite.

"OK," Gilby was saying as he paced the thermocarpet, "now explain what exactly you did."

Clunky was stretched out on a settee. "I simply persuaded that trio of dimwits to sign us up."

"But instead of twenty-six shows, they're going to do fifty-two," said Molly from the doorway to the pantry. "That's, my lord, $104,000, 000 for the first year."

"It is," agreed the robot dog, allowing his silvery tail to wag a few times.

Gilby said, "But, according to Mrs. Leandro, they'd decided not to hire us at all."

"I had a short, private chat with Rowland Hemreson."

"And?"

"He cast the deciding vote, since Farr was already on our side."

"Yeah, but how'd you convince Hemerson to do that?"

Clunky chuckled. "I wasn't kidding when I mentioned having met the gink before, boss," he explained. "Nope, Rowland was a frequent customer of the bordello during my months of servitude. I happened to use my built-in vidcamera to take some interesting footage of his more ambitious activities and—"

"You don't have a built-in camera."

"I added that myself," said the dog. "Even by Hollywood moral standards, Rowland's performances aren't acceptable. He was happy to further my career in exchange for my promise of discreet silence."

"Blackmail," said Gilby.

"Right, and a basic negotiating tool," said Clunky. "I've got quite a library of footage stored inside me. We'll be able to use it to persuade other important bigwigs to smooth our path back into the mainstream of world entertainment, chief."

"How can you store pictures?" Gilby stopped in front of the dog. "I didn't design you to—"

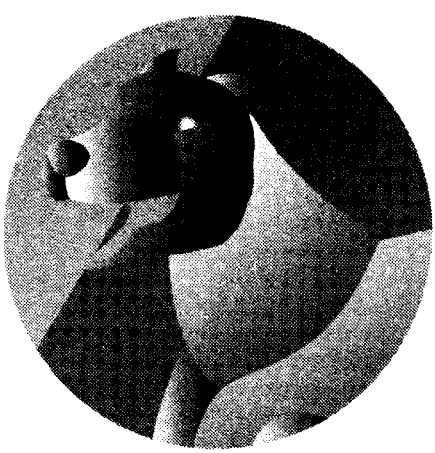
"You really haven't been paying sufficient attention," Clunky told him. "I've used my time away from you to improve myself."

"Even so, I—"

"I also taught myself to write scripts. And I'm damned good at it."

"Write scripts? But that's what I do on *My Pal Clunky.*"

"No, that's what *we* do," the dog told him. "Sit down and I'll tell you some of my ideas. OK?"



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Probability Zero

Mary Had a Little . . .

Dean McLaughlin

Microscopic, they're hard to tell one from another. Labels on tiny containers have a way of coming loose when stored at low temperature, and hand-scrawled notations can be difficult to read under the best of circumstances. Neither do color codes guarantee absence of error; not everyone who's color-blind knows it. And, when you know what you're looking at—or think you do—you don't always see what's there.

In short, it was the sort of mistake anyone could have made.

As the head was smaller than the usual human infant's, it was an easy delivery, the only complication being what to say on the birth certificate.

Mary and her live-in partner are suing the fertility clinic.

Sensing possible theological implications—Lamb of God, plus the fortuitous name of the mother (if indeed she can thus be described)—various religious bodies weighed in with opinions, some of which conflicted with others. However, the fact of immaculate conception was not in dispute, sterilized glassware and rubber gloves having been used throughout that part of the process.

As befits, the Vatican has maintained a dignified silence.

To the impatience of some other community leaders, and the apprehension of still others, the rumor that it may be of a blackface breed have been neither confirmed nor entirely discredited. Militant feminists, however, bubbled with delight at news that this unusual birth, which they assert must be miraculous, was female.

Several local restaurants have quietly removed roast lamb from their menu, at least until the excitement dies down.

National Enquirer offered $50,000 for exclusive photographs.

Meanwhile, the sheep farmer, who is not amused, is also seeking legal representation. "Them gentlemen down at the feed store been givin' out the hooraw," he complains. Vehemently he denies paternity of either newborn.

Skeptical, his wife is seeking a divorce.

The county clerk, in charge of vital records, has asked for a clarification of rules from the attorney general's office. The county agricultural agent has similarly requested guidance from his superiors.

Bills to outlaw this and that have been introduced in both houses of the state legislature as well as in the House of Representatives in Washington. In addition, a number of senators announced that they will carefully study the matter and all its ramifications.

Citing historical precedent however, one pundit suggested politicians might prefer to have sheep among the registered voters in their districts. That is, he says, if they don't already have them.

And while all this fussbudgetry proceeds, in the Caribeean (perhaps elsewhere, also —ask around) establishments of a more entrepreneurial nature discreetly offer their services. No questions asked. Any combination desired up, down, or sideways on the species ladder, though it's suggested that those such as elephants, whales, and hippopotami might present interesting challenges.

Ostrich eggs? Technical aspects need work, but soon now. Real soon. ■

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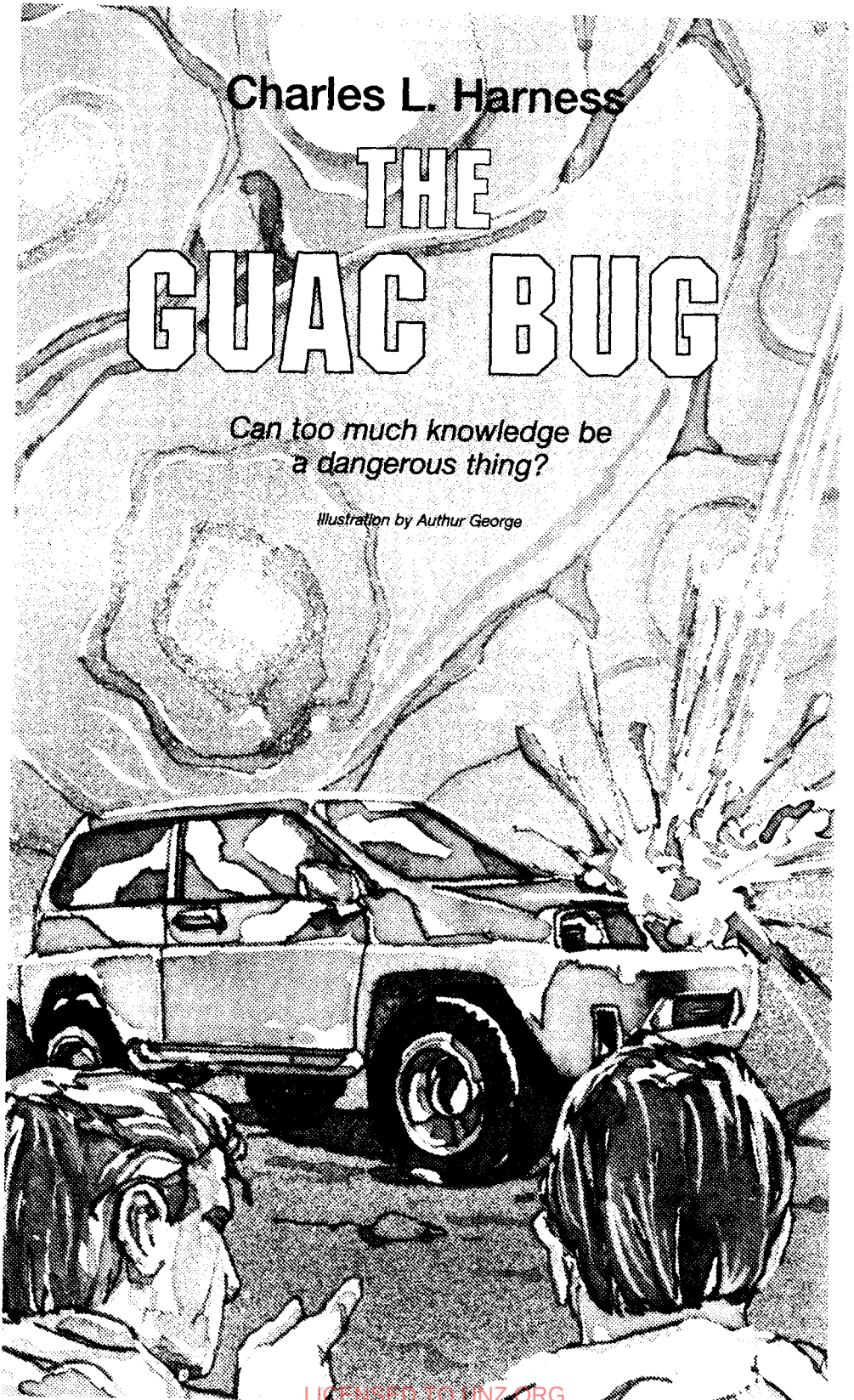

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The Meteorite

Quentin Thomas, lawyer, and his favorite client, Walter Gruen (Gruen Pharmaceuticals), had been motoring along the Skyline Drive that Wednesday morning. They had stopped at a deserted overlook, parked the car, got out, and they were looking down into the valley and the seven loops in the Shenandoah River, when something shrieked through the air behind them and exploded with a blinding light into the front of the lawyer's brand-new Pathfinder.

The two men stood paralyzed a moment, then rushed back to the car. The radiator was steaming and sizzling and gurgling. Whatever had hit it had left a six-inch hole in the grille. The coolant mix of water and glycol was dribbling away on something very hot and was immediately changing into steam.

Thomas put his hands on his hips and looked dubiously at his friend. "Meteor?"

"Meteor*ite*," corrected the chemist. "Can I have it?"

"It's all yours." The lawyer reached into the front seat for his car phone. "Meanwhile, let's see if the ranger can find us a tow truck." As he placed the call he was thinking a few feet farther west, and he . . . or Gruen . . . oh well. . . . No use thinking about it. They had been lucky. But never underestimate your chances of being struck by a meteorite. That woman in Alabama . . . the thing went through her roof . . . actually scraped her leg . . . And that village in India . . . one had hit a dog. "Oh, hello? Ranger? Look, I have a problem. . . ."

In the Lab

They were waiting as Thomas walked into the conference room. Gruen, of course. And Ben Blake, the chief chemist, and a young woman with intense dark eyes and sunken cheeks whom he had seen in the lab but whose name he did not know. Gruen introduced him to Dr. Lacey, bioanalyst.

"Mary" she said.

"Quentin."

In the center of the table lay two pieces of black rock, each half the size of a coffee mug.

"It's your meteorite," Gruen explained. "Net weight, about 3 1/2 pounds. Ben?"

"It's definitely from Mars, Quentin," said the scientist. "We've done a lot of work on it. Walter thought we should have this meeting before we publish."

Thomas eyed the two pieces thoughtfully. "Yes . . . quite right." He frowned. "Mars?" The word hung there.

Gruen smiled. "I didn't believe it myself at first. Actually, it's in good company."

Blake said, "Counting this one, there are now at least fourteen Martian meteorites in our museums. The five-kilo rock returned last year by Pathfinder Five—'PV'—is of course the current standard. Before that, it was the four-pound meteorite found in the Allan Hills of Antarctica in 1984—ALH 84001. Our little prize is geologically and chemically quite similar to PV and ALH 84001. PV and our rock were thrown high into the Martian air by a tremendous meteoric impact some fifteen million years ago. They were already four billion years old when that happened. PV fell back to the planet's surface but our rock was hurled into an escape orbit. It circled the sun for fifteen million years and was exposed to cosmic rays that modified its surface in characteristic ways. We can calculate the time it spent in space by radiometric dating. Some minor gravitational perturbation—maybe a passing asteroid—knocked it out of solar orbit, and so, Quentin, last year it hitched a ride on your auto." He handed Thomas a pair of plastic gloves. "Go ahead, pick it up. Either piece, both . . . You can't hurt them."

Thomas snapped the gloves on and picked up one of the pieces. It was black on the outer surface, but a mottled gray where the diamond saw had sliced through. Obviously, some sort of internal

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irregularities. Pores? he wondered. He looked up questioningly at Blake.

"We'll start with the easy stuff," said the chemist. "As you know, both PV and ALH 84001 have properties that strongly suggest life. Our rock has all these. Number one, the tiny globules of carbonate. We have similar chemistry on our own planet: creatures in Earth oceans take in carbon dioxide from the air and likewise convert it to carbonates. Second—within those globules, we find PAH's—polycyclic aromatic hydrocarbons, such as are produced by living organisms when they decay. Third, within the globules, we find two kinds of magnetic minerals, iron oxide and iron sulfide—components of certain Earth bacteria. Fourth—the rims of the globules contain structures suggesting that microbacteria had once lived there."

Thomas peered closely at the shard. "Suggestive . . ."

Blake said, "True, but at the outset, we must point out that each and every one of these four characteristics could have been produced inorganically, without the aid of any kind of life. However, we believed it practically impossible that all four could have been produced simultaneously inorganically, and in the same locus. And with that thought in mind, we investigated further." He paused, looked over at Gruen, who nodded.

The chemist continued. "So far, nothing really different from PV or ALH 84001. However . . .

Here his voice shifted into a dead laconic monotone, which Thomas sensed was an attempt to conceal excitement. "However, there's one very big difference. We recovered a viable life form from our rock. When we sawed open the rock we found a colony of something—microcells in an internal fissure. Apparently the colony was sufficiently deep inside to resist destruction by heat, and was chilled so quickly by the cold of space that it was preserved intact. Recall, ordinarily when DNA ages, it tends to break into small pieces, about one to two hundred base pairs. That didn't happen here."

Thomas thought back. DNA had been recovered from insects and vertebrates of a hundred million years ago, when dinosaurs ruled the earth. But he knew both PV and ALH 84001 were supposed to be over four billion years old. His eyes suddenly widened. "But—from *Mars?* Do you realize—?"

Gruen's mouth tightened in a half-smile. "Yes indeed. *Life on Mars.* But do we dare announce what we have? When the news gets out, the media all over the world will explode. Our labs would be in total disarray overnight. Oh, we know the full story will come out sooner or later, but right now we believe the publicity would seriously damage our research. We need more time. At the moment we think the Martian microorganism is useful, very useful. But is that the whole story? Can it also be deadly? Is there a downside? We don't think so, but we don't want to identify the source until we know more."

The lawyer nodded. "Makes sense."

Blake said, "Meanwhile our culture vats are working twenty-four hours a day. We now have several kilos of the product. We're preparing a paper for *Science*—no mention of Mars."

Thomas frowned. "Careful . . . premature disclosure could screw up your patent program."

"No patent," Gruen firmly. "We're dedicating it to the public."

Thomas raised his eyebrows. "No patent? It's just an academic curiosity? No commercial possibilities?"

"We're not certain," Gruen said. "But if it does what we think, it will be very useful indeed. And that's why we want it to be freely available to the public. Ben?"

"Watch this," Blake said. The lights dimmed. The screen on the opposite wall lit up. "A little drama recorded by the electron microscope. The blob in the lower right is a T-cell, one of the most important cells of the human

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immune system. Thirty minutes earlier we infected that cell with a Bis virus, which we assume is now in the process of integrating itself into the DNA of the cell and taking over command of the cell machinery. Now watch the upper left-hand corner."

At the mention of "Bis" the lawyer sat up straight. On the day the World Health Organization announced that HIV-vaccine was a success, the Center for Disease Control in Atlanta announced the outbreak of 37 cases of what was tentatively styled HIV-Bis, or Bis for short, followed the next month by thirty deaths. Like HIV, Bis attacked the immune system and thereby destroyed the body's defenses against the so-called opportunistic diseases, which then moved in and killed.

"*Bis?* Ah!" The lawyer noted a tiny blob moving in slow zigzags toward the right of the screen. It stopped, seemed to pulse and vibrate for a moment, then it headed straight for the infected cell.

"Your new bug?" said Thomas.

Gruen nodded.

The little creature hit the cell surface, paused, moved slowly along the surface, stopped.

"That's the exact spot where the Bis virus went in," Blake said.

"How does your boy know?" Thomas asked.

"Not sure, but we think Bis may have left traces of its sheath membrane dangling on the T-cell's hydrophilic surface. We can't detect it, but it's evidently a red flag to our guy. We call him Anti-Bis, incidentally."

Anti-Bis vanished.

The act seemed instantaneous, and Thomas started. "*That* was fast!"

"Wait—" said Blake. With his laser pointer he indicated to a second tiny disc on the screen. It was moving steadily toward the infected T-cell.

"Another Anti-Bis?" muttered Thomas.

"And still two more," said Blake, pointing with the laser, "They are all going in, right behind number one."

"Good God," whispered Thomas. "They hunt in *packs*?"

"Like wolves, or wild dogs."

Scary, thought Thomas.

The invaded cell began to shudder. It bulged, contracted, vibrated.

"If you could hear it," Gruen said, "it would sound like World War III. They're tearing the cell's viral component into little pieces. When they finish that, they go after any toxins in the cell that the virus may have had time to make."

"And then what?" said Thomas.

"After they clean up inside," said Gruen, "they all divide. From what we can tell, one stays inside, guarding the cell against future invasion. The rest crawl out again and go looking for free-floating virus and for more infected cells."

"But what if Mr. Bis mutates?"

"That's where it really gets interesting," said Blake. "Bis's mutation is in response to a chemical signal in the blood or wherever Bis is hiding. Maybe Bis smells his mortal enemy, like the rabbit scenting the stalking coyote. He quickly transposes a couple of his RNA codons. Ordinarily this would conceal him from certain cells in our immune system. It's almost as though it's an act of intelligence, but of course it isn't—it's simply a non-volitional chemical response. And it doesn't work. Anti is ahead of him. *He* mutates certain codons in his own nucleid strand, and Mr. Bis is once again highly visible, and helpless. Look." The chemist changed the slide and a luminous image shone on the far wall.

"Here's our Anti-Bis, enlarged at thirty thousand."

Thomas squinted at a throbbing sphere with a double wall and an internal cylinder. "Looks a lot like HIV."

"In general appearance, yes, but that's all. Mary?"

Mary Lacey said, "We've often wondered about the very first life on Earth—the protocell—how it was formed, what it looked like. Anti-Bis gives us the answer. Our earliest visible evidence on Earth is the stromatolites, stony columns

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formed by early bacteria, at least three and a half billion years ago. They lived on carbon dioxide, they had no nucleus, and were probably photosynthetic. We believe *those* life forms had evolved from even earlier forms that left no record. Our ancestral protocell most likely came into existence at least four billion years ago, probably under conditions quite similar to those that generated our Martian friend. All that was needed was hot water, ammonia, ultraviolet light from lightning, carbon dioxide, maybe energy such as the sun, or electrical energy from lightning."

She paused, looked around the table. Thomas thought at first she was just checking to see whether they were paying attention, but then he saw the faraway look in her eyes, and it seemed to him just then that she might be some prehistoric priestess standing on the edge of an ancient scum-crusted tidal pool, and she would lift her arms, and utter magic words, and life would begin.

She continued. "The raw materials were there. The ammonia and carbon dioxide reacted to form amino acids, urea, purines, pyrimidines, with phosphates coming in from abounding minerals. All the pieces of the jigsaw puzzle were present, jostling around, trying to hook up in the proper order. This finally happened, and probably by accident. It may have taken several million years for it to happen, but time was no problem. And finally life did indeed happen: click click click. The right pieces slammed together in that submicroscopic world, the nucleic acids joined hands, and we had the protocell."

Thomas looked around him covertly. Gruen and Blake surely knew all this, but they were leaning forward, as rapt as he.

Dr. Lacey said, "How does this protocell differ from other purine: pyrimidine assemblies?"

"For one thing, it's ravenous. But it's particular. It grabs up uracil, adenine, cytosine, guanine, but it does this in a certain picky order, and suddenly it finds it is making long polymeric strings. It spits them out as a copy of itself. That's how it replicates. And if it can't find free-floating molecules to gobble up, it attacks clusters and groups, anything not exactly like itself."

She focused on the lawyer, like a teacher boring in on a dull student. "Our ancestral protocell was a killer, Quentin, and it wasn't even yet a cell with a protective shell and all sorts of goodies inside, stuff to make spiders, elephants, Homo Sapiens. Here on Earth that came soon enough. On Mars, though, the seas dried up, the atmosphere blew away, and everything stalled. Until now."

Okay, Mary, he thought, I believe.

Gruen said, "All living things use the same genetic code. Hence it would appear that all life arose from a common ancestor. And here he is, Quentin, Anti-Bis: your great-great-great granddaddy, vicious, savage, hungry as a bear coming out of hibernation."

"If he's so mean and nasty," Thomas said, "why doesn't he attack every cell in sight?"

"Each of our cells wears a white hat," Mary Lacey explained, "An 'MHC'—major histoincompatibility complex. We condition Anti to our specific MHC's before he goes to work. Like explaining to guard dogs who the good guys are."

"So now what?" asked Thomas.

"Our obvious goal is Bis," said Gruen. "Maybe we've finally found the cure. But of course Anti has never been tried on real people. We have to set up test protocols with FDA. Terminal Bis patients have to join the program. It could be a total flop. And even before we get to that, we want to make more tests in glass."

Thomas frowned. "The rock is already public knowledge, and the microlife you found soon will be."

"That's fine, Quentin," Gruen said calmly. "We're dedicating it to the public. Anybody can make it."

Somehow this did not surprise the

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lawyer. He shrugged. "Bis is a twenty billion a year market, and you're giving Anti away? Why, Walter?"

"Basically, for ego reasons, I guess. And maybe a little guilt. Bis treatment is presently running well over ten thousand dollars per person per year, and it's not really very effective. That's just for the medicine. You pay that or you die a lot sooner. The things that worked for HIV are useless for Bis. It's like starting over, and if Anti-Bis works, and is controlled by the drug industry, its price will go through the roof. Industry will get rich, but a lot of people won't be able to afford the program. Of course a lot of the cost will be picked up by insurance. But a lot won't be. A great many people won't be able to afford the medicine. Without medication they die quicker, sometimes in two or three years after infection. But if Anti-Bis works, Quentin, inability to pay won't cost your life. With everybody able to make Anti, it'll cost about the same as diet pills."

Thomas pondered this. True, Bis medication was presently a multi-billion dollar a year industry, with at least half-a-dozen major suppliers, even though nothing really worked. Are they going to sit idly by while Walter Gruen tosses Anti into the public domain? "Suppose," he said, "someone else gets the patent?"

"How could they?" asked Blake. "We're first."

"We *are*, aren't we?" said Gruen. "First?" But there was uncertain edge in his voice.

Thomas's eyebrows arched. "Are you? Someday you may have to prove it. You ought to at least get your records in order."

"Such as?" asked Blake.

"For starters, right away deposit a culture at American Type Culture Collection—ATCC, in Rockville, and give them a full enabling written description on how to process the specimen. They'll preserve Anti in liquid nitrogen and they'll make samples available to anyone who asks. That should at least give you a legal date for a public disclosure."

As he drove home, the lawyer kept thinking . . . idealism . . . the willingness to forego immense profits in order to save lives . . . magnificent idea . . . and a little insane. It violated human nature. Say Anti-Bis works. What will a man pay for his life? His wife's? His child's? Every cent he has, all he can borrow. And Walter Gruen wanted no part of the deadly bargain. Fine, Walter, but how about your competition? Twenty billion dollars are breathing hot down your idealistic neck. For all you know somebody out there is planning right now how to jerk the rug out from under you and shatter your pretty dreams. Somebody out there will try to get a patent . . . *the* patent, and blow you to hell. God love you, Walter, it's good you own your own company. The board of directors of any public corporation would have fired you long ago!

Several Weeks Later

Quentin Thomas subscribed routinely to several watch services that alerted him to U.S. and foreign patents dealing in fields of particular interest to his clients, including of course Bis.

This morning he watched, fascinated and alarmed, as the text of the European patent application scrolled up on his monitor. He immediately called Gruen. "I'm e-mailing you a copy. We need to talk. I can get there within the hour. Better bring Blake in, maybe Mary Lacey."

"It's a European patent application," the lawyer explained. "They publish early, invite opposition, and if the application survives, it eventually issues, and has a high presumption of validity. It's different in the U.S. We keep our pending patent applications secret until they issue. But with the European system we're alerted to the fact that a U.S. case is on file and pending, because the European document refers to it, and claims

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the U.S. filing date for priority purposes. The inventor here is Francis Bakker. Anybody know him?"

"My opposite number at Catley-Torgsen—C-T," Blake said. "So C-T is now in the game. This could be serious".

In more ways than one, thought the lawyer. Officials at the competing pharmaceutical house had been accused of sundry unethical practices, including theft of trade secrets. He said quietly, "You'll note their priority date is three months after your deposit at ATCC." He looked across the conference table in sudden concern. "Ben, you *did* deposit with ATCC, didn't you?"

"Of course," said Blake. "I sent it special messenger. We have a receipt. It's official, ATCC 06-327."

"You included process details? How to culture and use the product?"

"All of that. You can see what they did at C-T. They ordered up a specimen of our ATCC 06, tested it for Bis, and promptly filed their patent."

"Barefaced thievery," mused Thomas.

"We've picked up rumors," Gruen said thoughtfully. "They say C-T is designing a new plant . . . big one . . . to make a new secret drug, something they call Cat-Sen. The secret is out, now. It's obviously a clone of our Anti-Bis."

Thomas had heard some of the rumors, but they had meant nothing to him at the time. Now they made sense. But C-T would want to be sure they had a monopoly before they built a plant. And for a monopoly they would need a strong patent. C-T management surely knew their man Bakker was not actually the first inventor, and that if the truth ever came out, their patent was dead. The stakes were high. And yet, C-T management must have studied ATCC 06 from all angles and decided it was not a threat to their patent. He had to assume that J. Reginald Alfrey, C-T's General Counsel, had advised John Gordio, C-T's president and CEO, that ATCC 06 was not a problem.

Why wasn't C-T worried about ATCC 06?

A sudden chill struck the lawyer. "Ben, I want you to put in a personal call to ATCC, right now, while we wait here. Ask the records clerk to e-mail you the process description, about 200 words, that you filed with ATCC 06."

"Quent . . . you don't think . . . ?"

"I don't think anything. Let's just find out for sure."

"Of course. Wait here."

Ten minutes later they had the answer. The Rockville agency had never received a process description.

Thomas studied the table glumly. So *that* was why C-T could plan to make Cat-Sen commercially. Their patent could not be knocked out by Gruen's earlier ATCC because no enabling description had accompanied the specimen. C-T would get a seventeen-year monopoly, plus another five years if FDA stalled clearance for their new drug. C-T was about to get legal custody of the beautiful child that Mother Gruen had brought into the world.

Gruen asked sadly, "Ben, how did it happen?"

"I don't know . . . our man . . . the messenger . . . no, that couldn't be . . ."

Our boy was bribed, thought Thomas. That's what he's trying not to say.

"I'll check with Personnel," Blake said. "I think he's gone.

Early retirement, thought Thomas. Wonder what C-T paid him.

"May I say something?" Mary Lacey asked hesitantly.

Gruen smiled encouragingly at her. "Of course."

"Well, I'm not sure whether this is good or bad. Under the circumstances, though . . . What I want to say is, we did in fact file a process description with our deposit of ATCC 06."

Thomas opened his eyes wide. "We did? Explain, please."

"The description is part of the specimen . . . about a thousand codons, some 3,000 nucleides, in the foreport of the specimen." She looked at their faces

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anxiously. "You see . . . don't you . . . ?"

Blake stared at her, then slapped the table, startling everyone. "Of *course*! Each codon calls for a specific amino acid. Each amino acid—there are twenty of them—is a particular letter of the alphabet. A string of one thousand letters, about 200 words. *Yes!* that would be the description we tried to deposit with our specimen!"

"Remarkable, Mary," declared Gruen. "But how did you happen to think of it? And *why*?"

"I . . . didn't trust Willie, Dr. Gruen. He suddenly had a lot of money."

It was that twenty billion dollars at work again, thought Thomas. That kind of money is alive, it has its own will. It is powerful, omnivorous, overwhelming. It simply blew the messenger boy away. But maybe like mighty Achilles, it has a vulnerable heel. *Code?* Hm.

"Does that change anything?" Gruen asked the lawyer.

"I'm not sure. Is the code readily decipherable by one skilled in the art? Mary?"

"I think so. It's just a simple substitution code. Leucine means 'e', proline means 't', and so on. There was no way to provide the key in the specimen itself, of course, but the decoder can work it out easily from well-known letter frequencies . . . e, t, a, o, i, n, and so on."

Thomas was tempted to feel relieved, but decided it would be premature. On the other hand it was always nice to know something that the opposition didn't. Indeed, something crucial and possibly even ultimately decisive. "Walter," he told Gruen, "I think it would be a good idea if you set up lunch with John Gordio soon, with me and his lawyer Reggie Alfrey along. Maybe we can help them decide whether they're going to build a plant to make Catsup."

"They call theirs Cat-Sen," said Blake.

"Catsup," said Gruen. "A meeting. Good idea. They've got a problem. When we tell them what we have, their board of directors is going to want a quick decision. But litigation in Federal court is currently running about five years. I think Big John will glad to talk to us. I'll call you, Quentin."

Lunch

It was The Club. It had no other name. It was the kind of restaurant where reservations were required even for a cup of cappuccino, the napkins were as thick as towels, the maître d' wore a pince-nez, and the calories were stated for everything on the simple linen-paper menu.

Quentin Thomas had eaten here before. He rather enjoyed the show and the sham, which he considered better than the food.

The four sat around the table, finishing coffee. John Gordio, president and CEO of Catley-Torgsen, and his longtime attorney, J. Reginald Alfrey, sat opposite Thomas and Gruen.

Thomas found the two executives an interesting study in similarities and contrasts. Both were wealthy. With his client it was old money: everything had been handed to him on a platter. The other had clawed his way to the top and now mostly delegated the clawing to underlings. Both exuded power. With Gruen it was quietly understated; one had to look twice. Gordio wore it like cologne.

"Shall we cut to the chase?" Gruen said.

Gordio nodded slightly. "Umph." He was not a tall man, and though not actually fat, he did not carry his excess weight gracefully. He waddled. If you were a woman, thought Thomas, you'd be six months pregnant. He was not surprised to learn that Gordio was addicted to pizzas "with everything."

J. Reginald Alfrey, on the other hand, looked trim and sat elegantly erect. Probably got up at seven and jogged, thought Thomas. Which maybe I should get into. After this is over. Maybe.

Gruen continued. "You'd like to build a fifty-million dollar plant to make Catsup."

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"That's *Cat-sen*," Gordio corrected mildly. "Jealous competitors love to mispronounce it. Cat-sen, Walter. From our corporate name, Catley-Torgsen. But you're right, we'd like a build a big plant to make it."

"You would need exclusivity," Gruen said.

Gordio took a sip of coffee, peered in Gruen's general direction. "Of course."

"A strong patent," Gruen said. The other executive grunted. Gruen said, "John, you cannot get a strong patent for your Catsup, at least not in the U.S."

Gordio smiled faintly. "You mean because of your ATCC?"

He looked over at Alfrey, lifted a shoulder slightly.

Alfrey said, "Walter, no American court would consider your ATCC an anticipation of our patent. You failed to file a description with your specimen."

"Beg to differ, Reggie. The front end of the RNA is the process description. Gives full details of the product, its isolation and use. Granted, it's in code, but it's readily decipherable."

"Code?" said Gordio. "Really? Hm." He exchanged glances with Alfrey.

The lawyer shrugged. "We thought maybe that's what it was. But we didn't have the key, we couldn't decipher it, and we let it go. Anyhow, by then we had completed our invention. Why do you mention your ATCC?"

"Because," Gruen said, "just now, ATCC 06 is a sword of Damocles hanging over your patent. If a court says one skilled in the art can read that code, ATCC 06 is a good disclosure, your patent is anticipated, and Catsup is wide open, and you have no monopoly."

Gordio studied him dourly. "Walter, let's not be stupid. Bis will be a twenty-billion-dollar a year market. I want it. Just me, Walter—not you, not anybody else. Don't mess with my patent, Walter."

There was a grim edge to Gruen's smile. "Twenty billion is nineteen billion clear profit, John. There'll be lots of poor people who can't pay, and they'll die. My way, they can live, and you and I can still stay in business. C-T is doing well right now, with no Catsup. You don't need exclusivity."

"The Board meets next month," Gordio said, "and they're going to authorize the new Cat-sen plant."

"We doubt that very much, John. Quentin?"

Thomas said, "Tomorrow morning we are filing a petition for a Public Use Proceeding in the Patent Office, under 37 CFR 1.292."

"Public . . . use . . . ?" The C-T executive looked blank. "Reggie . . . ?"

Alfrey frowned. "Public Use . . . rarely used, but it's in the rules. Basically, if somebody thinks he knows of a public use a year prior to your filing date, he can demand that the office hold a hearing. Really no problem, John. They'd have to prove that one skilled in the art could easily read their coded process description."

"So we're not worried?"

"No, we're not worried."

"And we can get a decision out of the Patent Office in time for the Board meeting next month?"

Alfrey looked unhappy.

"John, Reggie," Thomas said, "Public use proceedings are now running about two years, from date of filing to final decision."

Gordio said sourly, "Walter, this is blackmail. Can we deal?"

"You mean, a quick decision, yes or no on your patent?"

"Yeah."

"Fine with me. What did you have in mind?"

"Reggie?"

"How about arbitration?"

Gordio frowned. "Could they win?"

"Not likely."

"Quentin?" Gruen said.

His lawyer shrugged. Everything would depend on readability of the code. Was Mary Lacey right? Could one skilled in the art readily decode the description? Very probably. It truly was a

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simple thing. And any way you looked at it, arbitration was Gruen's best chance. He said quietly, "Try this. Okay, if we arbitrate. But if the arbitrator finds that the coded description on ATCC 06 is readable by one skilled in the art, C-T will withdraw their patent."

Gordio and Alfrey studied each other a moment. "Okay," the executive said. "*Provided*—if this arbitrator fellow finds ATCC is *not* readable by . . . by . . ."

"By one skilled in the art," Alfrey interpolated.

"Yeah, then *you* agree that our patent is valid and enforceable, and that ATCC 06 infringes."

Thomas looked at Gruen, nodded.

"Agreed," Gruen said.

"Now, about the details," Alfrey said. "I suggest that we submit the question to the American Arbitration Association, go by their rules; it'll be a one-day hearing, testimony under oath, and limited to the question of readability of the code. We take the morning, you the afternoon. Or reverse—we don't care."

"Quentin?" asked Gruen.

"Sounds fine. Let Reggie draw up the papers."

Two weeks later the lawyers had agreed on the time and place for the arbitration and had exchanged witness lists. Alfrey sent Thomas a list naming thirteen witnesses—one to testify live and twelve by affidavit.

As the sole witness for Gruen, Thomas had retained Dr. Louis Ulnar, a well-known biology professor at Georgia Tech. The expert was scheduled to fly up to Baltimore-Washington International the night before the hearing. Ulnar had reported that he had easily decoded the process data on ATCC 06 and would so testify.

And now Thomas had a problem. He reviewed mentally the steps taken over a year ago by the staff at Gruen to deposit the specimen of Anti-Bis at ATCC, and especially how the printed process data had failed to arrive at the depository. Blake had sent the packet by a young employee who worked in the mail room. It was pretty clear to Thomas that C-T had bribed the boy. Walter Gruen agreed with him, but pointed out that they could make no accusations without proof. When the lawyer hinted that the flawed messenger might be but the tip of an infiltration iceberg, and that market pressures might push C-T into inflicting even greater damage the executive hinted that Thomas was paranoid.

Maybe I am a little paranoid, thought the lawyer. But suppose I were J. Reginald Alfrey, totally without scruples, with an unlimited budget, what would I do to make sure C-T wins the arbitration?

He continued the thought. Professor Ulnar is our sole witness, and the hearing must be completed in one day. Alfrey merely has to delay Ulnar's departure from Atlanta for twenty-four hours, and he wins. Outright murder? Probably too risky. Anyway, Alfrey is not the type. Still . . . twenty billion . . . it gets dicey. I'll have to call Ulnar, tell him the risks as I perceive them, give him a chance to change his mind.

Suppose he decides to come on up anyway? And they stop, him? Or suppose he decides—maybe at the last minute—*not* to come? Either way, I'm going to need an alternate witness. A very secret emergency witness. No one at Gruen will know, not even Walter. How do I make sure my alternate gets past Gordio's goons? A challenge!

The Hearing Opens

"Judge." They still called him that, even though he had retired from the bench over ten years ago. Retirement had made sense, at least at the time. He and his wife Helen had planned an extended world tour, trying to catch up on a dozen vacations they had never taken. And then she had contracted a terminal illness and it had all collapsed. That had been a hard time. To hold himself together he had written a book, he had guest-lectured in the law schools, and he

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had been accepted as an arbitrator by the American Arbitration Association. And *that* was the avocation he liked best. He loved being the sole arbiter and judge in a complex case that both parties thought needed immediate one-day resolution, with a final decision from which no appeal could be taken. It was like being the United States Supreme Court, with all nine Justices rolled into one.

He did not sit on a high custom-upholstered chair behind a bench at these hearings—no, generally just a simple office desk and chair, facing a similar chair for the witness and fold-up tables for the parties. Everything was recorded by closed-circuit video, and video transcripts were available by the end of the session, backed up by the transcripts prepared by the stenographic reporter. There was no 'bar' to shut out an open-court audience from the proceedings. Indeed, none was needed, for the public was excluded. He could wear a business suit at the arbitration, of course, like the lawyers, but no, he chose the robe. Black, flowing, authoritative. The tradition of the robe was indeed ancient. It far predated even the Roman *fora*. One sees it in the friezes of the law courts of the ancient Egypt and in the bas-reliefs of Hammurabi's Susa. It symbolized four millennia of the peaceful settlement of men's quarrels. And of this, he, Penfield Grant ("Old Granite"), was still an active part. For which he was grateful, for he dearly loved to umpire these intellectual fights. This one promised to be a good one.

How had they come to select him as arbitrator? Easy. Under the expedited procedures in the Arbitration Rules, a list of five candidates was submitted to each party. Each party could strike two candidates. The parties had stricken a total of four, probably people they knew and thought were biased one way or the other. That had left him.

He had read the pre-hearing briefs submitted by the parties, and he knew it involved technologies way over his head—codes, chemistry, microbiology.... Well, he still knew how to listen and how to ask questions.

So, he thought, as Wellington said at Waterloo, let battle commence. He looked over his desk at the two groups. "Good morning, gentlemen."

His audience returned the greeting, and he continued. "We have for arbitration the case of Catley-Torgsen, whom we will style as Claimant, versus Gruen Pharmaceuticals, Respondent. Normally the Association attempts to complete a hearing in one day, and I understand that is not only acceptable here, but is insisted on by the parties. So we will get right to it. Counsel, will you please identify yourselves."

"J. Reginald Alfrey, for Catley-Torgsen, Claimant."

"Quentin Thomas, for Gruen Pharmaceuticals, Respondent."

"Thank you, gentlemen, please be seated. I presume the other gentlemen are principals and witnesses. We'll get to everybody in due course. Meanwhile, let me sum up the strictures imposed on this proceeding, as stipulated by the parties.

"There is only one issue: is the process information allegedly coded into American Type Culture Collection Number 06 readily comprehensible to one skilled in the art? If I decide that it is, then in that case Claimant will withdraw its patent application covering the ATCC product. But if I decide that it is not thus comprehensible, Respondent agrees that Claimant's patent is valid and agrees never to manufacture the product in question.

"Testimony will be limited to the issue as stated. "Claimant opens, completes by twelve noon. Cross examination limited to fifteen minutes per witness. An hour for lunch. Resume at one, Respondent comes on, completes by four. Closing statements, thirty minutes each." He looked up sharply. "All agreed?"

The two lawyers said, "Yes, your honor."

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"Good, Mr. Alfrey, opening statement?"

"Yes, Mr. Arbitrator. Catley-Torgsen is a very large pharmaceutical manufacturer. We have plants all over the world, with over fifty thousand employees. Our annual research budget is over a billion dollars. As part of our research we developed a new drug which we call 'Catsen.' This new drug has great potential in the treatment of the well-known devastating viral disease, Bis. Much testing still has to be done, of course.

"If it proves out, we want to go into commercial production. For this we would need exclusivity, which of course means patent protection. So we duly filed for a patent. Respondent Gruen learned about our patent, still pending in the Patent Office. They claim that a certain biological specimen anticipates our patent. The specimen was indeed deposited with the American Type Culture Collection more than a year before we filed our patent. Ordinarily this would be sufficient to invalidate our patent. However in this case no enabling process data accompanied the deposit, so in effect there was no public disclosure, nothing available to one skilled in the art as to how to reproduce or use the specimen. Gruen, however, takes the position that all necessary process data are coded . . . their word, your honor, into the preliminary nucleid stretch in the specimen, and that the coded description can be readily decrypted by one skilled in the art. We contend that the description is impossible to decrypt and that therefore the specimen does not anticipate our patent. To prove our case, I will offer one witness plus several affidavits. Shall I proceed with my witness?"

"Just a moment." The arbitrator looked over at the other lawyer. "Mr. Thomas, you can make your opening statement now, or reserve it for your afternoon session. If you give it now, I will extend Mr. Alfrey's time pro quanto."

"Later, your honor."

"Good. Call your witness, Mr. Alfrey."

"I call Dr. Emil Kintsch."

John Gordio had introduced Thomas and C-T's expert witness to each other earlier in the morning, and the Gruen lawyer had detected nothing cryptic about the cryptologist at the time. With his average height, honest brown eyes, friendly smile, Kintsch could pass as a solid citizen, a pillar of any community. And yet, thought Thomas, within a few minutes, with a little help from Reggie, this man of unassailable integrity will begin twisting the truth into fantastic shapes. Sad. It's the money.

Emil Kintsch

"Your full name," said Alfrey, "and the city where you reside?"

"Dr. Emil Kintsch, Columbia, Maryland."

"Are you presently employed?"

"Yes. I own and operate Kintsch Associates, a cryptology service."

"And what does that involve?"

"Two things, basically. We prepare encryption algorithms for clients, and we attempt to decrypt encrypted messages submitted to us by clients."

"What exactly is an 'encryption algorithm', Dr. Kintsch?"

"It's a computer program organized around a key. Say you want to send a secret message, such as 'We bid ten million dollars.' Now if the key is two digits, say '25', the programwould add 2 to the first letter in the message, and 'w' becomes 'y'. To the next letter we add 5, and 'e' becomes 'j', and then repeat. To recover the message, the receiver decrypts in reverse."

"How long would it take a computer to crack that code?"

"An ordinary P.C.? Nanoseconds."

"Not very secure?"

"No, but of course it was only a two-digit key, about ten bits on the computer. Since a bit would be either zero or one, that key would have two to the tenth bits, or only 1,024 possibilities. To achieve anything approaching even

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semi-security, one would need a key exceeding 128 bits. That would give a total of two to the power of 128 possible keys—which calculates to 3 followed by 38 zeros. The average mainframe processing a million possibilities a second would need 10 to the twenty-fifth years to try all key variations, with a fifty percent chance of success by the quadrillionth year. And yet the National Security Agency permits export of encryption software using a 128-bit key, so we must assume the government has computer capacity in the basements of Fort Meade that can readily decrypt algorithgms using a 128-bit key. Aside from that, we have been able to confirm that a student at the University of California, Berkeley, broke a 128-bit key in three and a half hours using a number of parallel work stations at the college."

"Are you saying that any code can be broken if given enough time and computer capacity?"

"Most can be broken, not all. They present varying degrees of security. In the extreme case, security can be unconditional, total. Brute force won't work. For example nobody can break a one-time pad unless he has the key."

"Explain 'one-time pad.'"

"It's a key that's used only once. Both sender and receiver have a sheet with the same random key numbers. The sheet is used once, then destroyed, and they go on to the next sheet. Or instead of a pad of sheets they can use a book. For example '201-4-6' would mean page 201, line 4, 6th word in the line. They say Rommel used a book in his African campaign."

"But a key can be useful, even though not totally secure?"

"Oh, absolutely. In fact, that's the situation with most keys. Security can be only partial, yet adequate, where commercially available computer capacity and time are insufficient to crack the algorithm. We call such algorithms 'computationally secure'. They can be broken, but not with resources available to the decrypter. For example a megacomputer within the budget of most large corporations can crack a 56-bit key in an average of three and a half hours, seven hours guaranteed. And yet such algorithm can be considered secure from most hackers and private citizens. To be secure from corporate competitors, a much longer key would be required, of course, and to defeat NSA, certainly one considerably longer than 128 bits. Actually, probably no repetitive code can be considered safe from NSA computers. The best the code user can hope for is to delay solution for a few days."

"Doctor, does your organization have access to megaframe computers?"

"Yes, several. In our own shop, of course, and on loan-time access in over forty universities."

"All told, roughly comparable to NSA's computers?"

"We're getting there."

"Dr. Kintsch, I hand you a one-page print-out. Can you identify it?"

"Yes. This is the message said to be encoded in ATCC 06. It consists of several thousand letters, G, U, A, and C, in apparently irregular order. You asked Kintsch Associates to decrypt the message."

"And did you?"

"No. We tried, but we failed."

"Explain how you tackled the problem."

"Our major efforts were based on the fact that since there were only four letters in the target message, a simple substitution code—letter for letter—was not indicated. So we asked the computers to try doublets—AC, AG, AU, and so on, looking for repetition and frequencies. This didn't help. We were able to set up a frequency table, and the computers worked at it for a couple of hours, but no English sentences popped up. Then we went to triads, such as UUU, CCC and so on. We knew, of course, that on a gene each triad made an amino acid in a human cell. But all we got was a string of amino acids. Well,

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of course we weren't looking for amino acids, that was a blind alley. It was as though the encrypter was teasing us. We went on to sets of quadruplet letters, then quintuplets, and so on. We ran over fifty megaframes in parallel for seven days and nights."

"And?"

"Nothing."

"You tried other systems?"

"Yes. Our associates worked simultaneously, while we were working in our own shop."

Alfrey returned to his table and picked up a sheaf of papers. He handed one set to Judge Grant, another to Thomas, and the third he handed to the witness. He addressed Grant. "Your honor, these are affidavits of experts in the cryptology field. I would like to describe them briefly for the record."

"Go ahead, Mr. Alfrey."

"First, affidavit of Dr. Marvin Mallory, now retired, formerly employed in the CIA Code Office. Dr. Mallory attempted to solve the message with known commercial algorithms, including DES, LOKI 91, IDEA, GOST, and Blowfish. Next—"

"Wait a minute," Thomas said. "They all say, they used their best efforts, and could not decrypt the target message?"

"Yes."

"Respondent has no objection to their admission."

"Thank you. Then I think we're about through on direct. Just one more question for Dr. Kintsch. Sir, in light of your own work and the findings of these twelve outsider experts, what do you conclude as to decryptability of the message alleged for ATCC 06?"

"Sir, I cannot swear that it is unconditionally secure. If it is decryptable, the key must be quite long, perhaps running to 512 bits or more. By way of comparison, we bear in mind that the Pentagon's H-bomb secrets and the CIA's roster of American spies uses only 128 bits. That leaves us with three possibilities. The target message is either computationally secure, or the encryptor used a one-time pad, or it's a bunch of gobble-de-goop nonsense."

"In plain English, the solution, if any, is beyond the skill of the art?"

"Yes."

"Nothing further," Alfrey said. "Your witness, counselor."

"Just one question," Thomas said. "Dr. Kintsch, were you aware that if you or any associates solved the message, you would thereby destroy your client's patent?"

The cryptographer stared owl-eyed at the lawyer. "Really? I had no idea!"

Thomas grinned. "Nothing further."

Dr. Kintsch was excused. He bowed sternly to all and left the room.

"And that completes my testimony," said Alfrey. "It's only eleven thirty. I'd like to reserve my final half hour for closing."

"No objection," Thomas said. He glanced at his opponent from the corner of his eye. The man radiated victory. Not so fast, thought Thomas. It's not over yet. The arbitrator looked about the room. "Seems a bit early to recess for lunch. Are you ready with your case, Mr. Thomas?"

Respondent's lawyer was silent.

"Mr. Thomas?" repeated Grant.

"A moment please, your honor. I think—yes—"

There was a knock at the door. Everyone looked around.

Quentin Thomas called out, "Come in!"

The door opened, a girl in a checkered uniform entered, carrying a flat square box. The odor immediately filled the room. Her eyes connected with Thomas's. She smiled. "Pizza, anyone?"

Betsy

Alfrey squinted hard at her. He tried to say something, but his larynx was apparently temporarily paralyzed. He gurgled. Gordio stood, wide-eyed, whispered something unintelligible. Judge Grant simply sat, looked quizzical, and waited.

Thomas spoke to her quietly. "Any trouble coming up?"

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"No sir, not really. A man in a black suit stopped me in the hall. I told him Mr. Gordio had ordered the pizza, and he let me on by."

"Very good. And now perhaps you'd better leave the pizza in the hall outside. We'll get to it later."

"Yes sir." She reopened the door, put the box outside.

Alfrey demanded sternly, "Mr. Thomas, you know this young woman?"

"I do."

"Then get her out of here!"

"Gentlemen," queried Grant, "what's going on?"

"Your honor," Thomas explained, "may I introduce Ms. Hatfield. She is here on official business. She is in fact my one and only witness."

"Witness? Witness?" demanded Alfrey. "What are you talking about? What could she possibly testify to? How to make pizzas? Your honor, how can you permit this mockery? I demand that you act! Call Security!"

"Sit down, Mr. Alfrey. Ms. Hatfield, are you here to testify?"

"I am, your honor."

"Objection!" called Alfrey.

"Your honor," Thomas said, "I think I can throw some light on Ms. Hatfield's presence here."

"Please do."

"Somewhat over a year ago my client sent a messenger to ATCC in Rockville, Maryland with a biological specimen subsequently identified as ATCC 06 327, plus details of a process for isolation, culture, and use of the material. If matters had gone as planned, the messenger would have left the process document at ATCC along with the specimen, well more than a year before Catley-Torgsen filed its patent application, and such deposit would have constituted a bar to the patent under 35 USC 102. The messenger left the biological specimen but not the document, and he has now disappeared. A replacement document was eventually sent to Rockville, but too late to invalidate the patent." He paused and studied Gordio from the corner of his eye. The C-T executive was squinting thoughtfully at Ms. Betsy Hatfield. Yes, thought Thomas, the disguise worked, she got through, and now you're wondering whether you ought to be worried. Yes, Big John, you ought to be worried.

He continued. "Though we had left no printed description with the specimen, for the sake of completeness and in an excess of caution a Gruen scientist had encoded the culture details in the specimen itself, and she intended that this information be readily comprehensible to one skilled in the art. We had expected to prove this readability by a witness, a virologist coming up from Atlanta. He was to have flown up last night, but we received information at the last minute that he was the victim of a hit-and-run accident on his way to the airport. He is presently in traction in an Atlanta hospital." He looked briefly at John Gordio. The man's face was inscrutable. You bastard, thought Thomas. Would you have killed the man?

He resumed. "While we had no reason to anticipate foul play—and indeed, we accuse no one, nevertheless we thought best to play it safe, and be ready with a back-up witness. To ensure her safe passage, Ms. Hatfield comes to us under the cover of her actual employment, a delivery girl for Checkers Pizza. If she is permitted to testify I believe we can wrap up this arbitration within the hour."

"And we still object," declared Alfrey. "She's obviously not qualified. The whole thing is a farce!"

Grant rubbed his chin thoughtfully. "Should youth and a uniform disqualify her? I say no. She's eligible. A question remains, however. It's now nearly twelve. Shall we recess for lunch, or shall we play on through?"

"Respondent can stay," Thomas said.

Alfrey and Gordio conferred. "We too," the lawyer said. "But Mr. Gordio wonders if he could have the pizza?"

She brought the box back in and presented it to the executive with a curtsey.

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Grant said, "Will the reporter swear the witness."

She was sworn in, then took the witness chair.

Thomas said, "State your full name and city of residence."

"Betsy Hatfield, Columbia, Maryland."

"Age?"

"Seventeen."

"Are you employed?"

"Yes sir, I'm a delivery girl for Checkers Pizza."

"Full time?"

"No sir, just certain hours. I'm going to Howard County Community College full time."

"How did you and I meet?"

"One day the Finance Officer at the college called me into her office. You were there."

"I told you why I was there?"

"You said you were looking for a student—male or female—who had had biology in high school and who could do some homework and then testify about it in a patent case. You gave me a sheet with a lot of letters on it. You said it was a description of a biological specimen deposited with the American Type Culture Collection, and that it was in code. You asked me if I thought I could decode it. I said I didn't know anything about codes. The whole thing looked pretty doubtful. Also, Mr. Thomas, meaning no disrespect, I couldn't figure you out. I thought maybe you were actually . . . after . . . oh never mind."

Thomas smiled. "So what happened next?"

"You said, take the paper home, think about it, call you if I wanted to tackle it. You said, if I solved the code, your client would pay my college expenses."

Alfrey was up and objecting. "Your honor! You hear this? She's barely out of high school. This witness is obviously not a qualified cryptanalyst. She cannot be permitted to testify in this very complicated matter."

"Overruled. This is interesting—let's listen."

"So you took it home?" Thomas said.

"Yes sir. I called you that night and read off the solution to you. Somebody at Gruen called the Finance Office next day. For which I thank you, Mr. Thomas."

"The pleasure is ours, Ms. Hatfield. Now then, did I give you any help? Any tips, like try this, or try that, or try such and such a system?"

"No sir. You said I had to do it all on my own, no help, no coaching, or it wouldn't count. I was even afraid to use my P.C."

"But you solved it. So explain how."

"Yes sir. Well, I looked at the text. There were four different letters, G, U, A, and C. And since it's a biological material, that translates to guanine, uracil, adenine, and cytosine. The 'U' means we're looking at RNA, and a string of RNA nucleides. RNA synthesizes proteins in the cell. It does this by stringing together amino acids. There are twenty amino acids in our cells. Each amino acid is called up by its own special set of nucleides in the RNA. These sets are called codons, and each codon is made up of three nucleides. For example, the codon UUU calls for phenylalanine, UCU for serine, UAU for tyrosine, and so on. There are more codons than there are amino acids, so some amino acids are coded by several different codons. Also, one codon means 'start', and several mean 'stop'."

"Ms. Hatfield," Thomas said, where did you get this information?"

"I had biology in high school, Mr. Thomas. I was pretty good at it. Remember?"

"Yes, of course. Please go on. What did you do next?"

"Well, the next step was to write the message out as a series of codons, then translate each codon into its corresponding amino acid."

"Why do that?"

"Well, once you have everything down as the names of the acids, you can calculate the frequency of the names,

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then you can assign letters of the alphabet to the names. You do this with reference to the frequencies of the letters in an English text. You follow the same procedure Poe used in solving the code *The Gold Bug*."

And now *The GUAC Bug*, thought Thomas. "What frequencies did you use?"

"Poe's frequency list is adequate: a, o, i, e, h, n, r, s . . . I forget the rest. But I used linotype frequency, e, t, a, o, i, n, s, h. . . . Quite similar to Poe's, but probably a bit more accurate for current English, especially as to frequencies of 'e' and 't'."

"So you assumed it was a simple substitution code, a given amino acid meant a given letter?"

"To start, yes sir, I thought I'd try that. Actually, substitution is the only kind of code I know. We used to pass notes with it in school. Okay?"

"Of course." We all did, thought the lawyer. "Go on."

"After I tabulated the amino acid frequencies in the message, I called the most frequent amino acid, 'e'. That turned out to be leucine. Also, the 'stop' codons, UAA, UGA, and UAG set off several three-letter words that I suspected might be 'the'. If I was right, that confirmed 'e' and right away gave me 't' and 'h'. So I called proline 't' and that made histidine 'h'. It looked good. Next I went to the two-letter words. Several had a 't'—and pretty soon I had 'at', 'it', and 'to', which gave me the vowels. I filled in all the letters over the names of the respective amino acids, leaving blanks where I had yet to determine the letter. Filling in the blanks was duck soup. 't_is' is of course 'this', and since 'o_' is probably 'or' or 'on', I looked ahead a little to see which would make the best sense. If it's 'or', I get '_iter', and then 'liter' right away, so 'o_' had to be 'or'. Actually the only two-letter word that gave me any trouble was '_1', but I finally decided the blank was 'm', which I got after I filled out 'hu_an'. The easiest two-letter word of course was '_ _'."

"Which was?"

"'cc', Mr. Thomas. What else?"

"Of course. How long did it take you to completely decode the message?"

"About an hour. I'm afraid I sort of rushed it, because I didn't want to be late for work."

"I now show you a page of handwritten script. Can you identify this?"

"Yes sir. This is the message as I decoded it and wrote it out."

"Offer in evidence, your honor, photocopies to opposing counsel and Mr. Gordio."

Alfrey walked over, snatched the sheets from Thomas's hands, gave him a venomous scowl, walked back to Gordio. They began scrutinizing the papers.

"That completes my direct. Your witness, Mr. Alfrey."

"Yes, just one minute, please." He continued to study the exhibit as he carried it toward the girl. He stopped and appeared to mark something in the text. "Now, Ms. Hatfield . . . ah, may I call you Betsy?"

"And I'll call you Reggie? Sure, Reggie, go ahead."

Grant put his hand over his mouth.

"Well, perhaps on the other hand . . . we'd best hold off on first names. Ah, Ms. Hatfield, you said the message used only twenty different amino acids?"

"Yes sir."

"And every letter in the message was represented by an amino acid?"

"Yes sir."

"You've sworn to tell the truth, Ms. Hatfield."

"Yes sir."

"But not *every* letter in the message has its corresponding amino acid, does it?"

"I do believe it does, Mr. Alfrey. Did you have some particular letter in mind?"

"I hand you your own translation, Ms. Hatfield. Would you please read the highlighted phrase?"

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"Sure. It says '. . . extracted in a flask . . . ' Okay?"

"Fine. What amino acid stands for the letter 'x', Ms. Hatfield?"

"Oh, I see your problem. Actually, there is no amino acid for 'x', or 'z', and four other letters, which I forget just now. Whoever designed the message used 'e-k-s' for 'x'. There are amino acids for each of those three letters. That's what he did. I simply smoothed out the spelling."

"Ah! You admit you altered the text!"

"I guess you could say that. I also put a period at the end."

"So you lied when you said—"

Thomas was on his feet, but Judge Grant beat him to it. "Knock it off, counselor," he growled.

"Withdrawn." The cross-examiner gave the witness a sidelong glance. "Ms. Hatfield, what arts are you skilled in?"

"Not much of anything, I guess. Except maybe cooking. I make pretty good breaded veal cutlets. And last Thanksgiving I fixed the turkey all by myself, for eleven people. I—"

Alfrey interrupted. "Biology? You had only high school biology, no biology in college?"

"Yes sir."

"You're not really an authority in the field of microbiology?"

"No sir."

"Or pharmaceuticals?"

"No sir."

"Code breaking? You never worked at Fort Meade?"

"No sir."

"What's the chemical name of aspirin?"

"Acetyl salicylic acid."

That stopped him for a moment. He stood and looked at her, puzzled. "How did you know that?"

"That was the password in our girls' club when I was in sixth grade."

Reggie, thought Thomas, you have just dug yourself a hole you'll never get out of. You have proved one doesn't have to be skilled in any art to read the code.

The corporation lawyer seemed to sense that cross had not gone well. "Nothing further."

Thomas said, "No redirect. And if Ms. Hatfield is not needed further, I think she would like to be excused. She has a class at HoCo in thirty minutes."

"Science?" asked Grant.

She said, "No sir, ballet." And holding her arms over her head, she twirled in a perfect pirouette, then headed for the door.

The arbitrator sighed, shook his head, looked at his watch. "It's one o'clock. A choice again—do you want to recess for lunch, or wind it up now?"

"I have no rebuttal," Alfrey said, "but I do have an important motion."

"On *my* time?" clipped Thomas. But then he thought, you are going to shoot yourself in the foot. "Oh well, go ahead, shoot."

Alfrey drew himself up firmly. "Move to strike Ms. Hatfield's testimony in its entirety. By her own admission she is not skilled in any art relative to ATCC 06. By prior written agreement, the parties were each bound to offer evidence only from witnesses skilled in the art. A pizza delivery girl simply doesn't qualify as an expert."

"Oppose," Thomas said quickly. "In the first place, there is nothing in our arbitration contract that limits witnesses to those skilled in the art. Second, despite lacking any special skills, our pizza lady solved the code quickly and handily. *A fortiori*, one actually skilled in the art of microbiology would have been able to do the same."

"I agree," Judge Grant said. "Motion denied. Anything further? Nothing? So let us conclude. I declare this hearing terminated." He turned to the computer terminal on his desk and began typing slowly, hunt-and-peck. As he typed he spoke in a firm clear voice. "I . . . find . . . for . . . Respondent Gruen Pharmaceuticals."

Alfrey watched this in dismay. The printer whirred in near silence, Grant pulled off the document, signed it with

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a ball-point pen, and handed copies to the lawyers. "Mr. Alfrey?" Claimant's counsel looked numb. The jurist finally had to touch the man's hand with the edge of the paper before his fingers reached out for it.

"And now," Grant said amiably, "we are going off the record." He nodded to the reporter. "Ms. Johnson, we thank you for your assistance here. You are excused. As you leave, would you please switch off the TV camera." As the door closed behind her the arbitrator addressed the group. "I think I can now give you the basic rule that governs this case and all cases like it. The rule is short and simple, but nobody is required to stay."

Nobody moved.

As he continued the trace of a smile seemed to flicker around his mouth. "The rule is this: 'One successful pizza delivery girl beats thirteen failed experts.'" He rose from the desk and started toward the door. In a moment he was gone. ■

IN TIMES TO COME

Our next issue is our annual July/August "jumbo" issue, offering roughly twice your usual dose of the things you read *Analog* for. Bob Eggleton did the cover, for "The Ice Dragon's Song," a new Bud Sparhawk novella of adventure on that frigid moon Europa. Our second novella, Daniel Hatch's "Slow Drowning," takes place *much* closer to home, in both time and space. In fact, it could happen at any time, and we would be the participants. But reading about it in the abstract is one thing, and experiencing it with those caught up in it is quite another. . . .

We'll also offer a goodly assortment of other fiction, including Stephen Baxter's first *Analog* appearance, a new short story by John W. Campbell Award winner Michael A. Burstein, a novelette by G. David Nordley, and the conclusion of Joan Slonczewski's *The Children Star.*

Finally, our science fact article is something special. Some thirty years ago, *Analog* writers were dealing with "Mars rover" robots in both fact and fiction, though the "fact" then was about the earliest stages of research in that direction. But last year the first *real* Mars rover, Sojourner, "walked" on the Red Planet, and Geoffrey A. Landis, a physicist well-known to *Analog* readers for both his fiction and his science articles, was actively involved. Here he shares that experience, and I can't remember any other article that could give you a better feel for what it's like to "do science"!

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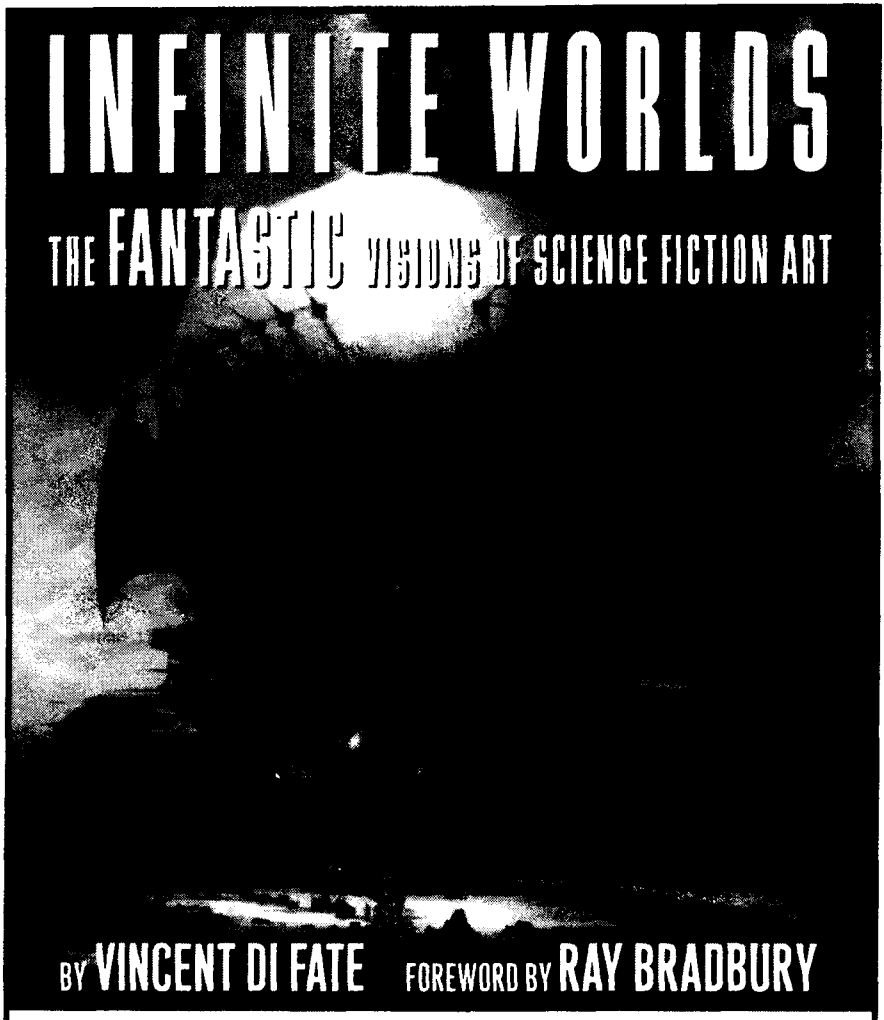

From movie posters to book covers, from raging raptors to video villains, here is the definitive collection of science fiction art. Artist Vincent di Fate has compiled nearly 700 images from the worlds of science fiction literature, television, and film to represent 150 years of graphic imagination, including work by Frank Frazettta, Michael Whelan, Leo and Diane Dillon, and many others. With its dazzling four-color illustrations and fascinating text, *Infinite Worlds* is a treasure every art and science fiction devotee will want to own.

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THE REFERENCE LIBRARY Tom Easton

Cosm, Gregory Benford, Avon Eos, $23, 344 pp. (ISBN: 0-380-97435-5).
A King of Infinite Space, Allen Steele, Harper Prism, $23, 312 pp. (ISBN: 0-06-105286-8).
The Great Wheel, Ian R. MacLeod, Harcourt Brace, $24, 458 pp. (ISBN: 0-15-100293-2).
Impostor, Valerie J. Freireich, ROC, $5.99, 346 pp. (ISBN: 0-451-45616-5).
The Book of Knights, Yves Meynard, TOR, $21.95, 222 pp. (ISBN: 0-312-86482-5).
The Cyborg from Earth, Charles Sheffield, TOR, $22.95, 285 pp. (ISBN: 0-312-86407-8).
Virtual Unrealities: The Short Fiction of Alfred Bester, Vintage, $14, 366 + xiv pp. (ISBN: 0-679-76783-5).
Kirinyaga: A Fable of Utopia, Mike Resnick, Ballantine / Del Rey, $23.95, 293 pp. (ISBN: 345-41701-1).
Triplanetary, Edward E. Smith, Old Earth Books (P. O. Box 19951, Baltimore, MD, 21211), $15, 287 + xviii pp. (ISBN: 1-882968-09-3).
First Lensman, Edward E. Smith, Old Earth Books (P. O. Box 19951, Baltimore, MD, 21211), $15, 306 + xviii pp. (ISBN: 1-882968-10-7).
The Postmodern Archipelago, Michael Swanwick, Tachyon (1459 18th St., #139, San Francisco, CA 94107, 415-285-5615), $7.50, 66 pp. (ISBN: 0-9648320-6-2).

We are used to seeing Gregory Benford playing glorious games with physics, notably in the long human versus mechs series (which concluded with *Sailing Bright Eternity*, reviewed here in Mid-December 1995) played out on the galactic backdrop. A few of his tales have had a tighter focus, zooming in on the physicist's lab and work. The most famous of these is surely *Timescape* (1980), which won a Nebula and gave its name to an excellent publishing line (which died far too young).

Now he gifts us with **Cosm**, begun a decade ago, when theoretical physicists had just begun to talk of how universes might bud off from each other like yeast cells. The opening scene is Brookhaven National Lab, where young black woman physicist Alicia Butterworth is preparing to collide uranium nuclei, dealing with activists and bureaucrats alarmed by the word "uranium," and objecting to Brookhaven's preemptive claim to first look at "her" data. She bulls ahead, the experiment starts on schedule, and all is going very, very well when . . .

BOOM! Nothing radioactive, mind you, but there's a hole in the beam line and a shiny, fizzy sphere the size of a basketball sitting in the middle of the debris. What is it? Between the title and the cover blurb, there's no mystery: Alicia has cooked up a mini-Big Bang. Her Cosm is a whole new universe, or at least a window on one.

And away we go. There is absolutely no way Alicia is going to let Brookhaven

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have this treasure. (They've only claimed her *data*, after all.) She absconds with the boodle back to her home base at the University of California Irvine, where she must deal with teaching chores, conniving academic politicians, a Brookhaven that is threatening to sue, a lackluster love life, and . . . Mostly she deals with all that by punting it into a corner. The Cosm is the center of her life, and her post-doc and grad student concur entirely, even after the Cosm releases a flash of energy that crisps the latter.

What's going on? Benford is seizing his opportunity to show you the development of a universe in the lab, at warp speed. A Cosm, he says, is just what cosmology needs, and any physicist or cosmologist who got her hands on one would of course be obsessed, would hover over the miracle to watch and watch and watch, and would feel indeed "a king of infinite space" (the *Hamlet* quote appears as a part opener, as well as on the cover of the Steele novel below). Meanwhile the crazies are emerging from the woodwork—Alicia is playing Goddess, after all, creating universes, and she must be stopped!—and the Feds are moving to confiscate her creation. Brookhaven has made a bigger one, which is evolving a little faster toward its own energy flash. And the theoretician she enlisted is turning out to be a very interesting fellow.

This one's a joy for any fan of hard SF. It's the real thing, and it's a treat.

If you yearn for a nice, traditional SF adventure loaded with high-tech marvels, space habitats, and Belters, seek no further than Allen Steele's **A King of Infinite Space**. It begins today, when a pair of spoiled rich kids, high on booze and drugs, screw up on the highway and die.

Our Hero, Alec Tucker, wakes up in a roomful of beds. He doesn't know a thing—an internal coach has to tell him how to eat—and the other beds are occupied by others in similar straits. Soon, however, he is able to function well enough to be put to work scrubbing the castle of Mister Chicago. In due time, he recognizes one of his fellow scrubbers as Shemp, the buddy who died with him. A bit later, he realizes that the Castle is a space station in the Belt.

What's going on? The reader recognizes the clues easily enough. Alec has been frozen and revived, the time is the far future, Steele's orbiting habitat, Clarke County, is now a monarchy, and what's that you say? The Mafia has gone as interplanetary as the Zodiac? Mr. Chicago's castle has zodiacal designs in those floors Alec is scrubbing? Mr. Chicago is the Big Green Cheese, the capo of capos, a Godfather as much in the heavens as his namesake? What's he planning?

Doesn't matter. Alec has learned that his long-dead girlfriend was frozen too, and her head is still on ice at Clark County. Shemp has been promoted to a position where he can express long-smoldering resentment over the demeaning nickname Alec gave him long ago. The atmosphere is turning nasty. So Alec's outta there, stealing an escape pod, squeezing just enough delta-vee out of its limited fuel supply to hitch a ride on a freighter, and bound for the Earth-Moon system. He doesn't know quite how he will rescue Erin, but he plans to try.

So. There's the adventure, the derring-do, and the reader's cheers are ringing through the living room. But surprises await. All is not what it seems. And you, Dear Reader, are destined to be still more satisfied when this one ends.

Enjoy.

Ian R. MacLeod's debut novel, **The Great Wheel**, has earned plentiful plaudits for its depiction of civilization in the aftermath of global warming and ozone depletion, overpopulation and famine. Europe is a bastion of wealth and privilege, its people shielded from plague by

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biotech implants and tailored viruses, from solar heat by orbiting sun-shields, and from want by a roboticized agriculture watered by clouds stolen from Africa and elsewhere. Africa is a desert, its mingled remnant peoples crowded into the Endless City along its northern rim, from Morocco to the Black Sea, and supported in part by European largesse dispensed in a very traditional mode. Other parts of the world are similarly divided, but the tale's focus is the boundary between Europe and its massively exploited colony to the south.

This is not greatly surprising, for the colonial past has a powerful grip on the imaginations and consciences of the descendants of the colonialists. There is a sense of guilt and debt, as well as a lingering sense of superiority over all those Wogs and Gogs. And the present holds the seeds of more guilt. Growing populations faced with shortages of food and jobs have long wished to move to Europe. When I was there in the 1950s, the immigrants were few enough to be exotic. Today they are a flood, and even nice people can feel threatened as the accents and complexions of their neighborhoods change. There are even calls to send the immigrants home where they belong and then to bar the door. We can hear very similar messages in this country.

Yet Europe (the industrialized north, really) requires the resources of all those Goglands. It can buy them or steal them; either way the "developing" countries lose their resources and are doomed to remain deprived. When those resources include water (those clouds), they are deprived even of the means to feed themselves. They must move or die. When they move, they must head toward whatever land of milk and honey is within reach, and when the way is barred, they must stop and settle. Hence the Endless City.

How do Europeans respond to such a situation? Some take advantage of it, for the Endless City is an endless supply of customers and workers. Some try to help, at least enough to salve their consciences. The Church—much changed since our day—sends priests such as Father John to minister at chapel and clinic, and here is where MacLeod has set his tale.

Father John feels for the people among whom he must live. Their ways baffle and confuse him, but when he notices an apparent surplus of myeloid leukemia cases, he looks for a cause. He even finds one in the habit of chewing koiyl, an analgesic, euphoriac leaf. He learns that the leaf is contaminated, hunts down the sources of leaf and contamination, discovers evidence that Europe may bear far more guilt than anyone wishes to recall, and confronts those forces of commerce and politics that wish to retain the status quo.

In the end, Father John even finds something of an answer. But that is by no means all of the story. MacLeod has constructed an intricate portrait of a living world, of technologies and politics and people, every bit of which rings true, from the illness of Father John's brother to the lady bishop, from drowned Paris to agricultural fairs. This is a story that convinces, that returns at night to haunt the reader's dreams, and it is thus far more powerful than others that have also exploited the North African milieu (e.g., George Alec Effinger's celebrated *Fire in the Sun* series).

The only flaw is perhaps the terminal coda, where MacLeod suggests that in space may lie escape from our colonialist heritage, and that in the end the Church must always turn its back on heaven.

The fourth volume in Valerie J. Freireich's consideration of far-future racism is **Impostor**. Once more the Order-seeking Jonists are insisting that only the base-line human form is the ideal, the Right and Proper Way to Be a human, and all other forms—meaning the descendants of those genetically engineered to survive on difficult worlds, or

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to have useful talents—are subhuman monsters. Aliens are even further beyond the pale, and indeed, within a century of meeting them, the Jonists of the Polite Harmony of Worlds had exterminated the Bril.

The Jonists like to think of themselves as rational, too. Thus any humans who build their lives around religion are nearly as excluded as the Altered. And now the Harmony is facing off with the Emirates, Moslem worlds where women are valued only for their ability to produce sons. Harmony residents who have ties to the Emirates are being deported.

Enter the cops, yanking exobiologist Marcer Brice out of his classroom, throwing him into a pen, herding him aboard ship, and dumping him on Bralava with the Emirate military honcho Idryis Khan a'Husain. Why? Brice was born in the Emirates, but only because his parents were on a business trip. He's an Altered—he can echo-locate—but he is also an Academician, a scholar, accepted as a near equal. Something strange is going on, and why is a'Husain trying to seduce him?

In due time, Brice gets the idea. The men of the Emirates are getting houris, holy wives, from a world they call Paradise. These women don't talk well and they are accompanied by nasty pets called jinn, but they're lovely and they bear only sons. In fact, Sons of the Prophet such as a'Husain, temperish and powerful, and sterile to boot.

Brice is a remarkably pigheaded fellow, but that gives the author a chance to explore the Emirate society a bit, show the place of women and the power of Sons, and introduce characters who will be of surprising importance later on. In due time he learns that there is a biological puzzle behind much of what is going on and accepts the chance to figure it out. The biology is suspect but intriguing, and it gives Freireich a chance to show the Jonists slowly, slowly coming around to a more inclusive view of their fellow beings.

If you enjoyed Freireich's earlier books, don't miss this one.

The Book of Knights is Canadian writer Yves Meynard's first English-language fantasy novel, and it is quite charmingly Oedipal. It begins with Adelrune, foster child, growing up tyrannized by rigid orthodoxy, the Rule and its Commentaries. Even before he can read, he craves escape, and when he discovers an ancient tome in the attic, he is motivated to study the Rule as the only available way to learn to decipher the text of the tome. In due time, he learns that the tome is *The Book of Knights*, learns all the tales of eld and adventure and honor, and resolves to become a knight himself. Before long, he discovers a bloody doll on the toymaker's shelf, vows to free her, and runs away from home.

Stupid kid? Well, the *Book* assured him a suitable knight-trainer was to be found in a valley three days' journey from town, direction unspecified, and so it turned out. Magic is afoot, and not least in the person of that trainer, Riander, and his ensorcelled manse. The boy learns quickly, pays the price of his training, and departs on his initial quest. Adventures ensue, he vanquishes foes, proves his mettle, and gains honor, and when he returns to the town of his birth, a knight indeed, he finds that fulfilling his vow is both easy and hard, gives both relief and pain, pride and shame. He learns somewhat of the ambiguities of life, and now he must embark upon his knightly wanderings.

A pleasure to read, reminiscent of but more mature than Michael Ende's *Neverending Story*. Watch for Meynard's name in thefuture, and while you're waiting, look for the Canadian SF magazine *Solaris*, of which he is the literary editor.

The latest in Charles Sheffield's Jupiter series of SF novels in the tradition of the Heinlein juveniles (*Higher Education*, *Billion-Dollar Boy*, and

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Putting Up Roots, so far) is **The Cyborg from Earth**. I found it less charming than the others, partly because the premise is just too fairy-talish and the tale itself too familiar in its broadest outlines, at least to anyone who grew up on those Heinlein juveniles, Tom Swift, and the like. Of course, it is a juvenile itself, and I have just said it captures precisely the feel Sheffield is after. If I had met it when I was a kid, I'd have loved it. So should the current generation, if they can but look away from the screen long enough to sample a few pages.

Meet the Kopal family. It builds the spaceships for Earth's small empire and is wealthy by any standard. Its traditions dictate that its offspring must apply for admission to the Space Navy, passing tests of fencing and horsemanship (among others), be admitted, and serve before stepping to the corporate helm. Those who fail to make the Navy or are dishonorably discharged are disowned and disinherited.

Meet Jeff Kopal, who faces the last of his Space Navy admission tests (horsemanship) today. He's not very good at such things, and he knows it. He'd rather be tinkering with an air car motor. He takes after, says his very ill mother, his long-vanished Uncle Drake. Cousin Myron and Uncle Giles, he's sure, would just as soon he vanished too.

He blows the test, of course. But to everyone's surprise—certainly his!—the Space Navy accepts him. Unfortunately, while Cousin Myron is off to Central Command to be groomed for higher things, Jeff is assigned to a small ship bound for Node 23 and a leap to the Messina Dust Cloud far away in the Galaxy, where the evil cyborgs of the Confluence are reportedly scheming to secede from Sol.

Cyborgs? It is not long before Jeff, injured and cast away with two "jinner" (engineer) friends, discovers the truth of that, as well as the truth of what the Space Navy is really up to, which has a lot more to do with the Confluence's technological marvels and family scheming than with any real threat of secession.

Technological marvels? Meet Simon Macafee, an inventor straight from the Golden Age of pulp SF, Tom Swift Junior grown old and gray. Wonder at the card he gives Jeff, which carries a replica of the constellation Dragon. And finally. . . .

Sheffield stops before the terminal wrap-up so common in other novels. There is thus room for a sequel, and any youngster who sticks with the tale this far will hardly be able to wait.

In his introduction to **Virtual Unrealities: The Short Fiction of Alfred Bester**, Robert Silverberg proclaims Bester (1914-1987) "among the two or three finest writers of short science fiction who ever lived." He was dazzlingly inventive and he knew how to make his stories trot, as anyone who has read his famous "Fondly Fahrenheit" can attest (you thought Bradbury wrote that one? Nope—that was *Fahrenheit 451*); if you haven't read it, you'll find it here, along with sixteen others, including two pieces that are new to print.

If you like these, you'll want to dig his novels out of the library. *The Demolished Man* (1952) won the very first Hugo. *The Stars My Destination* appeared in 1956 to considerable acclaim. After he retired from his job as a travel writer and editor, he added *Extro* (1975; aka *The Computer Connection*), *Golem*^{100} (1980; he thought it his best), and *The Deceivers* (1981), as well as a couple of non-SF novels.

A decade ago, Mike Resnick began what was to become what he calls "the most-honored science fiction book in history" with "Kirinyaga," a tale of conflict between cultural value-systems set in one of a set of orbiting worldlets devoted to utopias. Over the years, he followed it with nine more stories of the attempt to recapture the Kikiyu Right and

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Proper Way, as well as an essay to remind his many critics "Uh . . . Guys—My Name Isn't Koriba."

"Kirinyaga" won a Hugo. "For I Have Touched the Sky" won the Hayakawa Award. "The Manamouki" won a Hugo, a Golden Pagoda Award, and a HOMer Award. "Song of a Dry River" won a HOMer. "When the Old Gods Die" won Locus and HOMer awards. Three of the stories made Gardner Dozois's Year's Best SF anthologies. *Every one* of the stories was nominated for several awards.

Calling the resulting book, **Kirinyaga: A Fable of Utopia**, "the most-honored science fiction book in history" may sound like marketing hype, but I would say the claim is justified. One could even say more, for Resnick is a writer of very smooth fiction that often seems—and sometimes is—very light. But he is also a writer of depth; he has a great deal to say, he says it well, and when he provokes as much outrage as he has done with the "Kirinyaga" series, he demonstrates that what he says is worth the saying.

What more can one ask? Only whether the bookstore still has a copy for you. Go see.

Old Earth Books has reprinted the first two (of six) volumes of E. E. ("Doc") Smith's Lensman saga, **Triplanetary** and **First Lensman**, with an introduction by John Clute to remind those who have forgotten (or who are so young that they think *Star Wars* invented space opera) that food chemist Edward E. Smith almost single-handedly—quite in the mode of his square-jawed, noble, male, white, human heroes—invented the sub-genre. Or at least climbed to the top of this particular peak of the sevagram, built a palace, and pulled up the ladder.

We're talking super-science planetary disintegrators and the slobbering vileness of the evil Eddorians. Action galore! Nonstop momentum! Loads of fun!

At least, that's what a lot of folks thought when the series first appeared in the 1930s and 1940s. Today, Doc Smith's rambunctious space adventures are remembered mostly because they gave the name "Boskone" to the Boston-area science fiction convention held every February. To those on the cutting edge of current SF, Smith is thoroughly and rightly forgotten, an anachronism by any standard, bad enough even in his own time to justify all the sneers ever aimed SF's way. To reread him now is, frankly, to wonder what our predecessors used for a critical sense (I wonder much the same about *Star Wars*).

But hey—it's history, it helped make SF what it is today, and its mode is by no means dead, even in print. If you like action-adventure SF, this may be just your thing.

Briefly Noted

If you have an interest in the more recent history of SF, you may wish to pick up a copy of Michael Swanwick's **The Postmodern Archipelago**. The first of its two essays, "A User's Guide to the Postmoderns," stirred up a certain amount of fuss when it first appeared (*Asimov's*, 1986) and declared cyberpunk dead even before most folks knew it existed. "In the Tradition . . ." (*Asimov's*, 1994) provided a kindred analysis for modern fantasy but—to Swanwick's disappointment—proved less controversial. Both are worth the reading.

Also from Tachyon: Peter S. Beagle's **The Rhinoceros Who Quoted Nietzsche and Other Odd Acquaintances** ($14, ISBN 0-9648320-7-0) is a predictably enticing and satisfying collection of eight stories (three of them from Beagle's early days) and four essays. Nancy Kress's **Dancing on Air** ($10, ISBN 0-9648320-5-4) reprints her 1993 novella concerning ballet, murder, and bioengineering. ■

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BRASS TACKS

Dear Stan,

Jeff Kooistra asks, in his January 1998 article, "Big Rocks": "Why? Why would the ancients build with such big stones?" That Jeff, a native of Michigan, would ask such a question astonishes me. Michigan is the place where cow tossing was first introduced. It is also one of several states where truck bowling is rising in popularity.

You are probably wondering what cow tossing and truck bowling have to do with archeology, engineering, and the subject of large stones or, in Jeff's technical parlance, "Big Rocks." All three of these activities belong to a class of phenomena known as Guy Things.[1]

Just as cow tossing, whose technical objective is to see how far a fully grown cow, preferably deceased, can be thrown using simple mechanical devices such as catapults. Most wives, when told of the cow tossing endeavors of their husbands, ask—like Jeff—"Why?" Most guys, on the other hand, say only "Hey, cool!", instantly understanding the meaning of such an enterprise as they imagine pulling the lever to release the flying bossie.

So, given that human nature hasn't changed all that much—as Jeff himself pointed out—it is easy to imagine several ancient guys hauling rocks and thinking "wonder just how big a rock we could move?" And, before you could say "Creeping Cheops," hundreds of guys all over the ancient world are out there busting their chops to move larger and larger rocks around—and sometimes even standing them on end (a great fraternity trick of the Britons who lacked cows to tip, which is another guy sport). Any wimp can build something with lots of little rocks but it takes a real *guy* to move a really *big* stone!

Oh yeah, truck bowling involves taking bowling balls up in airplanes and seeing if you can hit one or several target trucks. This has several advantages as a guy thing—it's expensive, involves lots of noisy equipment, has a high damage component, and, best of all, is a complete mystery to women. Say, wouldn't that apply to most of these ancient structures as well?

[1] *Numerous learned articles on the Guy Thing phenomenon have been published in D. Barry's weekly columns*

JOHN C. SPARHAWK, JR.
Sparhawk@compuserve.com

Dear *Analog*,

In his "Alternate View" column in the January issue, Jeffery Kooistra asks why the ancients bothered to build with huge stones, when it would have been so much easier to use several smaller ones? I suggest that the difficulty was exactly the point. Abandoned structures were important sources of building materials. One way of ensuring something would last a long time was to build it with very large stones. Hiding evidence of how it was built would help, too.

JIM VAN ZANDT

Dear *Analog*,

This concerns the "Alternate View" article by Jeffery Kooistra (January '98). My wife and I saw the same Stonehenge show. It struck us how everybody is missing one easy way of sliding big loads, namely on ice. Yes, high pressure melts ice, but boulders don't melt their way to the bottom of an ice block, since glaciers have deposited "erratics" all over. The

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rocks in question were hauled together at the back end of an ice age. We may speculate that people were busy all summer getting a crop in, but might get together in winter for a little hunting and some public works projects. I wonder if Mr. Kooistra would be willing to test how introducing ice into the equation would affect the various theories.

Thank you for putting out such a stimulating magazine. I have been a subscriber for years.

WOLFGANG H. H. GUNTHER
West Chester, PA

Dear *Analog*,

In response to H. G. Stratmann's "The Eumenide" in the January '98 issue, which should have been named "Medea", since I do recognize the plot. . . .

I understand the point of being sure a mind-wiped murderer is truly mind-wiped. But for all the incessant repetition of Consuelo's "biological defect" and her extreme overreaction to "abandonment," did the author realize that what happened to her was far more than simple abandonment? It was betrayal, and while she had no right to kill, the story seems to imply she had no right to even be angry. She lived with a man, kept his house, and bore his children. Then he dumped her for a woman of higher status, and after a while, demanded the children back—so they could have two parents. But then, we seem to be edging slowly back into a period in which anything a woman does is wrong, and she herself is evil, whereas whatever a man does is accepted without comment.

PATRICIA (PAT) MATHEWS
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The author replies . . .

Although "The Eumenide" incorporates plot elements (including a quotation) from "Medea," its primary inspiration was the play quoted at the beginning, "The Eumenides". As in my story, the main focus in it is on the reactions of others to someone who has committed murder, and arguments over how the murderer should be treated. Also, my title includes an inherent ambiguity regarding who the "eumenide" is—the character who seems to be acting as an avenging Fury, or the one who acts in a way consistent with the literal meaning of that word, the "kind one" (see the last page of the story).

The two characters who describe Consuelo as feeling "abandoned" are both psychiatrists, and are using the word in a technical sense. Individuals like her with borderline personality disorder are characterized by "frantic efforts to avoid real or imagined abandonment"—that is, separation from or rejection by someone they intensely depend on and/or "love".[1,2] The various types of personality disorders (again, a technical term) often involve exaggerated, extreme versions of "normal" feelings and reactions. Thus, Consuelo's anger at her very real, reprehensible betrayal and "abandonment" by her lover is quite understandable. However, expressing those feelings by murdering him and their children much later was not the most appropriate response to those feelings, and was symptomatic of her particular biologically-based personality disorder.

Any statements in the story implying that Consuelo shouldn't be angry about how her lover treated her, or that a "double standard" should be used, are made by characters (i.e. the hosts of the TV program about her) whose ideas are clearly being held up for ridicule. Please re-read the story, and I hope you'll see the attitudes you mention and similar ones (i.e. simplistically identifying individuals as "evil", or turning tragedy into entertainment) are being satirized.

[1] Borderline personality disorder. *Diagnostic and Statistical Manual of Mental Disorders.* 4th edition, pp. 650-653. American Psychiatric Association. Washington, D.C. 1994.

[2] Borderline personality disorder.

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Comprehensive Textbook of Psychiatry, pp. 1438-1441. Kaplan H.I. and Saddock B.J., eds. William & Wilkins, 1995.

HENRY G. STRATMANN, M.D.

Dear Dr. Schmidt,

I found Mr. Kooistra's article, "Paradigm Shifty Things," to be almost unbearably stimulating, and I enjoyed the exchange in the January '98 Brass Tacks about it.

Regarding your editorial, "Natural Succession": it occurred to me that the reason "a skilled manager can *sometimes* effectively supervise a process he doesn't know much about" is that there are fundamental principles ruling the management of *any* organization. Some of these are undoubtedly already followed by most successful managers, even if they have never been explicitly stated, but others may exist that have yet to be discovered. This is not to argue against your statement that "there's no real substitute for understanding at the hands-on level"—that is certainly a necessary, although not sufficient, principle. It might be a fruitful exercise to try to describe an organization run according to these principles and how it would overcome the usual barriers to success (or perhaps some unusual ones).

By the way, the best stories in the January '98 issue were "The Question" and "The Eumenide."

THOMAS J. FIELDER
ANAHEIM, CA
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Dear Dr. Schmidt,

While I found your discussion of the stages of development of businesses and nations interesting, I think your perspective is slightly behind the times. Now, the final stage of development for a business is not management by accountants, but management by lawyers. They are playing ever more important roles in business in two ways:

First, they are used aggressively. A valuable employee has joined the competition? Sue 'em, even if he never signed a no-compete contract (*Wall Street Journal*, Nov. 25, p. B12). A hot new start-up has a product that leaves yours in the dust? Sue 'em for patent infringement (even if we lose, it'll tie them up for years and cost them money they might have spent on out-marketing us or developing even better products). And, while you're at it, make sure there's a patent attorney at the elbow of each and every engineer, filing a patent on every trivial idea. Just think you might hit it rich like Texas Instruments and reap billions in royalties! Those guys at Western Electric were real suckers with the transistor.

Secondly, they are used defensively. If they aren't doing the filing, businesses don't like to win lawsuits—they'd rather not get sued at all. What are the environmental consequences of a new parking lot? Just exactly what constitutes a "hostile work environment?" Where is the line between "disability" and "inability"? These, and many others, are increasingly litigious issues, and businesses, by handing them over to lawyers, are giving over to them big chunks of what were key corporate hiring and investment policies.

I am reminded of a story told to me by a distributor of semiconductors. In years past, he had become acquainted with an engineer with a then (and now) very successful U.S. semiconductor company. He didn't often get to this company's headquarters, but wnen, after a couple of years, he last did, he went to the building that housed the engineers, only to be told that his friend had been transferred to another building. When he asked why, he was told that the whole department had been moved, to free up the building for lawyers.

As to the analogy with government, I haven't done a count recently, but I would bet that, at all levels, lawyers outnumber managers and accountants combined.

STUART JOHNSON
Stuart.Johnson2@gte.net

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Dear *Analog*,

Your January, 1998 Editorial was, as usual, thought-provoking and very much to the point. I can give you another example which may widen the field of inquiry: the Environmental Protection Agency, in its early days under Ruckelshaus, was almost a model of what a Federal Agency should be, and rarely is, a place where the people knew what their job was and did it. Some very good science got done, and much good came of it. When someone was found, by EPA investigation, to be in violation of the law, the facts were turned over to the Justice Department for amelioration or prosecution, depending.

Then some idiot got the bright idea that EPA should have its own enforcement authority, so it was taken from the hands of the scientists and given to the lawyers. Laboratories closed, heads rolled. The EPA was no longer a fact-finding agency; instead, it became a policy-setting agency; and from being a watchdog, it became a pet poodle. Of all the monumental stupidities, companies which let loose more or less toxic effluents were charged with self-policing! They analyzed their own effluents—and still do, if you can believe it.

So, the question which was asked many years ago is still up in the air: "The World is not going to come to an end—but Mankind is. The only question is, when?"

EDWARD G. ROBLES, JR.

Dear Brass Tacks,

There might be something to Stan's complaint about the "accountant mentality" in today's society, but he missed the point in attributing the move to sell off the national park system to that mindset.

As he himself pointed out, the founding fathers were idea men; their most powerful idea was constitutionally limited government, constrained by a system of enumerated powers. Selling off the parks is a libertarian idea. It's motivated by the belief that maintaining a system of parks isn't a proper role of government at any level, and that even if it were, the *federal* government had no enumerated power to do so. The insanely large debt the federal government has run up may get us a hearing, but we'd be out to get rid of those parks even if the nation were debt-free, and running a surplus!

Nor, let me add, is the expansion of the park system, which shows no sign of ending, motivated by a perceived lack of camping sites. No, I'm convinced that it's really driven by a contrary ideology common among people in the government sector, which is hostile to private property in general, and private ownership of land in particular. That land isn't being set aside for future generations (the original rationale for the park system), it's being set aside with the intention that no one will *ever* be permitted to own it.

In closing, I'd like to say that the real tragedy of the commons is that we insist on having them, despite all we know about human behavior.

BRETT P. BELLMORE
Capac, MI

It seems to me that you're assuming that everybody trying to sell off the parks shares your motivations, and I don't think that's even remotely true. As for myself, I share many of your principles, but I've already explained why I don't buy your conclusion in this case, so I won't repeat it here. You can find it in my April 1997 editorial, "Public vs. Private."

R. Bohl:

In your letter commenting on Kooistra's "Paradigm Shifty Things," you ask "why the hyphens" in "light-speed-limited gravi-whatsis!" Simple answer: *clarity*.

Three-quarters of the way through your paragraph four is a good example of why the hyphens. "An observer . . . would see a time varying gravitional [sic] distortion of space. . . ." That is ambiguous, despite

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"a" modifying some noun within that sentence. Is time (a time) varying gravitional distortion? Or is the gravitional distortion varying time (a time)?

Add one hyphen and meaning becomes clearer: ". . . see a time-varying gravitional distortion," thus making clear and specific the relationship of time, varying, and the gravitional distortion.

There are plenty of reference sources. Don't avoid hyphens out of laziness or not-knowing. Learn to use them to help clarify word relationships.

E. ELDRED

Hear, hear!

Dear Editor:

Your fact article by diplomat M.A.G. Michaud, "Organizing Ourselves for Contact" (January '98), completely misrepresents the nature of contact between civilizations, treating it as relations between autocratic nation-states instead of as communications between individuals here and afar. What someone here might have to say to anyone out there, is not a message "between civilizations" but between individuals who are likely to be in disagreement with other parties, and in capitalist competition with them, both here and there. The autocratic relations Mr. Michaud describes are suitable only for civilizations at war, where individual actions can have destructive effect. The relations between cultures at peace are only between individuals, on both sides, in disagreement and competition with each other, made possible by the peace between them. It is really grandiose of Michaud to, as he says, "question what right a small, self-appointed group had to speak for the entire human species." They don't speak for a species, but for their individual, private interests, to similarly diverse alien interests. Imagine what business would be like with a foreign country here under Michaud's principles of contact—like relations between autocratic powers of pre-industrial times. When the aliens call, just list their servor on the internet. Government should have nothing to say about it. If the aliens are really advanced, one could hardly expect to receive from them some unified expression of a "civilization" fantasized as a homogenous organism.

GEORGE LYONS
Glyons@worldnet.att.net

Dear Dr. Schmidt:

Michael A.G. Michaud's article on contact protocols in the Jan 1998 *Analog* may have offered a possible answer to Fermi's question, "Where are they?" They (alien civilizations) are out there. They are just tied up in diplomatic red tape.

RON BURK
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raburks1@home.com ■

We welcome your letters, which should be sent to *Analog*, 1270 Avenue of the Americas, New York, NY 10020. (CompuServe: 71154,662. Internet: 71154.662@compuserve.com.) Space and time make it impossible to print or answer all letters, but please include your mailing address even if you use e-mail. If you don't want your address printed, put it only in the heading of your letter; if you do want it printed, please put your address under your signature. We reserve the right to shorten and copy-edit letters. The e-mail address is for editorial correspondence *only*—please direct all subscription inquiries to: P. O. Box 54625, Boulder, Co 80322-4625.

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UPCOMING EVENTS Anthony Lewis

5-7 June 1998
AD ASTRA 18 (Toronto area SF conference) at the Radisson Hotel, Toronto, ON. Registration: C$35 until 15 May 1998. C$40 at the door. Info: Ad Astra 18, PO Box 7276, Station A, Toronto, Ontario, Canada M5W 1X9; email: redbeard@yorku.ca; URL: http://terra.phys.yorku.ca/~white/adastra.html

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12-14 June 1998
B'HAMACON 4 combined with DEEPSOUTHCON 36 (Deep South area SF conference) at Parliament House Hotel, Birmingham, AL. Guest of Honor—Michael Bishop, Fan Guests of Honor—Buck & Juanita Coulson, TM—Bob Tucker (smooooth). Registration: $25 until 15 May 1998, $35 thereafter. Info: DeepSouthCon 36, Box 94151, Birmingham, AL 35220-4151.

26-28 June 1998
SHORE LEAVE 20 (Maryland area Star Trek-oriented conference) at Hunt Valley Marriott, Hunt Valley, MD. Info: Shore Leave 20, PO Box 6809, Towson, MD 21285-6809; (410) 821-5563. email: ShoreLeave@aol.com or heyer@stsci. edu; URL: http://members.aol.com/ShoreLeave/

26-28 June 1998
CONESTOGA '98 (Oklahoma SF conference) at Sheraton Tulsa, Tulsa, OK. Guest of Honor—Connie Willis, Artist Guest of Honor—David Cherry, TM—Mark Simmons, Fan Guests of Honor—Susan & Jim Satterfield. Registration: $20 until 1 May 1998, $25 thereafter. Info: Conestoga '98, PO Box 54037, Tulsa, OK 74155-4037; (918) 836-5463. email: wentwortkd@centum.utulsa.edu; URL: http://www.ionet.net/~rlmorgan/kon/conestoga.html

5-9 August 1998
BUCCONEER (56th World Science Fiction Convention) at Baltimore Convention Center and nearby hotels, Baltimore, MD. Guests of Honor—C. J. Cherryh, Milton A. Rothman, Stanley Schmidt, and Michael Whelan; TM—Charles Sheffield. Registration until 15 June 1998: $130 (£94), supporting $30 (£22), children +4 to 12 $65 (£47), children .75 to 4.0 FREE (all ages as of 5 August 1998). (These are the latest posted rates as of the time this column went to press.) This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition—the works. Info: Bucconeer, Post Office Box 314, Annapolis Junction, MD 20701. e-mail: bucconeer@bucconeer.worldcon.org; URL: http://www.bucconeer.worldcon.org

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13-16 August 1998
MARS SOCIETY FOUNDING CONVENTION at The University of Colorado, Boulder, CO. Speakers—Mike Griffin, Robert Zubrin, Chris McKay, Carol Stoker, Kim Stanley Robinson, Gregory Benford. Registration—$140 before 30 June, $180 thereafter. The purpose of the Mars Society will be to further the goal of the exploration and settlement of the Red Planet through: broad public outreach, support of ever more aggressive government sponsored Mars programs, and initiating Mars exploration on a private basis. Papers for presentation are requested dealing with all matters (science, engineering, politics, economics, education, social impact, etc.) associated with the exploration of Mars. Abstracts of no more than 300 words should be sent by 31 May to: Mars Society, Box 273, Indian Hills, CO 80454. URL: www.nw.net/mars ■

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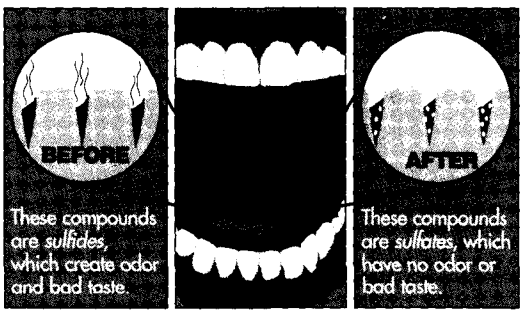
Finally—a "cure" for bad breath!

For years, the cause of chronic bad breath has been misdiagnosed, but a dentist's research has led to TheraBreath™, a dramatic treatment system that works naturally and effectively.

These days, people spend a great deal of time on their health and fitness in order to look and feel their best. Unfortunately, many people around the world suffer from a condition that cannot be cured at a health club, spa or even a hospital: chronic bad breath or halitosis.

The only solution is the TheraBreath™ system. Because halitosis originates in the mouth, it is virtually undetectable by your own sense of smell. Without proper treatment, chronic bad breath can lead to a loss of confidence and self-esteem, and it can even result in depression. What's needed is a quick and effective treatment that works naturally with no side effects.


BEFORE
These compounds are *sulfides*, which create odor and bad taste.
AFTER
These compounds are *sulfates*, which have no odor or bad taste.

Oxyd-VIII™ *(concentrated pH-balanced ClO_2)*, the active ingredient in TheraBreath, transforms these odor-causing sulfides to sulfates, which have no taste or odor.

A scientific solution. Bad breath does not originate in the digestive system, and the food you eat has no direct effect on your breath. Certain foods, however, contribute to the production of sulfurous gases in the back of the mouth. Acids in coffee and proteins in dairy products exacerbate the problem. Mints and mouthwashes intended to mask or prevent bad breath actually worsen the condition because sugar and alcohol dry out the mouth. The only effective means of eliminating the sulfur gas production is to introduce oxygen to the bacteria, causing them to produce tasteless, odorless sulfates.

Effective, safe and natural. At his California Breath Clinic, Dr. Katz has perfected a five-step program for treating halitosis. By using these products on a regular basis, chronic halitosis sufferers can end their problem. The TheraBreath system eliminates the problem of bitter or sour taste in the mouth, improves general periodontal health and will even whiten teeth. Unlike mouthwashes that are flavored heavily or designed to taste like medicine, TheraBreath has a mild spearmint flavor. These products are all-natural and simply introduce a greater amount of oxygen into the mouth's chemistry.

Try it risk-free. The TheraBreath System is an effective, safe and easy-to-use solution to a troubling problem, but don't just take our word for it. Try this product for yourself with our risk-free home trial. If you are not fully satisfied, just return it within 30 days for a full refund.

TheraBreath™ . . . . . **$39.95** $6 S&H

Please mention promotional code **2805-12962.**

For fastest service, call toll-free 24 hours a day

800-992-2966

To order by mail, send check or money order for the total amount including S&H. To charge it to your credit card, enclose your account number and expiration date.

Virginia residents only—please include 4.5% sales tax.

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TECHNOLOGY UPDATE

One scientist's vision revolutionizes the hearing industry, benefiting millions of people...

Crystal Ear® uses sophisticated electronics to provide affordable, cosmetically-pleasing and easy-to-use hearing amplification.

One day a friend asked my wife Jill if I had a hearing aid. "He certainly does," replied Jill, "Me!" After hearing about a remarkable new product, Jill finally got up the nerve to ask me if I'd ever thought about getting a hearing aid. "No way," I said. "It would make me look 20 years older and cost a fortune." "No, no," she replied. "This is entirely different. It's not a hearing aid...it's Crystal Ear!"

No one will know. Jill was right. Crystal Ear is different—not the bulky, old-styled body-worn or over-the-ear aid, but an advanced personal sound system so small it's like contacts for your ears. You will hear sounds your ears have been missing for years. Crystal Ear will make speech louder, and the sound is pure and natural.

DON'T TAKE OUR WORD FOR IT...

"My father spent over $5000 on another brand. I showed him my Crystal Ear, he tried it, and he decided it worked better than his brand, even though it was a...fraction of the cost!"

—A satisfied Crystal Ear user

It is smaller than the tip of my little finger and it's almost invisible when worn. Put it in your ear and its ready-to-wear mold fits comfortably. Since it's not too loud or too tight, you may even forget that you're wearing it!

A fraction of the price. Hearing loss is the world's number-one health problem, but in most cases it goes completely untreated. For many millions of people, hearing devices are way too expensive, and the retail middlemen want to keep it that way. What's more, treating hearing loss the old retail way can involve numerous office visits, expensive testing and adjustments to fit your ear. Thanks to Crystal Ear, the "sound solution" is now affordable and convenient. Almost 90% of people with mild hearing loss, and millions more with just a little hearing dropoff, can be dramatically helped with Crystal Ear. Plus, its superior design is energy-efficient, so batteries can last months, not just weeks.

You'll feel years younger! Crystal Ear arrives ready to use, complete with batteries, two different fitting sleeves, a cleaning brush and even a carrying case. It is made in the USA, using state-of-the-art micro-manufacturing techniques that cut costs dramatically—savings that we can pass on to you.

Don't be fooled by high prices. No hearing device, no matter how expensive, can eliminate background noise, despite claims by the manufacturers. Crystal Ear does not promise miracles—just an affordable, sound solution to many common hearing problems.

Risk-free. Try Crystal Ear and hear what you've been missing. It comes with a 90-day manufacturer's limited warranty as well as our risk-free home trial. If you're not satisfied, return it within 30 days for a full refund.

Crystal Ear®:
Three credit-card payments of $99.95 $19 S&H
If not purchasing a pair, please specify right or left ear.

Please mention promotional code **3464-12961.**

For fastest service, call toll-free 24 hours a day

800-992-2966

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